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OF THE

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VOLUME 5

1918

CONTENTS AND INDEX

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VOLUME V, 1918.

ABBREVIATIONS. — D. = Discussion; I. = Illustrated.
Names of authors are printed in *italics*.

The issue of the JOURNAL for January has been delayed, due to the closing of all manufacturing plants by order of the United States Fuel Administrator.

George C. Whipple
President, Boston Society of Civil Engineers
1917–1918

Vol. V JANUARY, 1918 No. 1

BOSTON SOCIETY OF CIVIL ENGINEERS
FOUNDED 1848

PROCEEDINGS

NOTICE OF REGULAR MEETING.

A REGULAR meeting of the Boston Society of Civil Engineers will be held on

WEDNESDAY, JANUARY 23, 1918,

at 7.45 o'clock P.M., in CHIPMAN HALL, TREMONT TEMPLE, BOSTON.

Business of the Meeting.—To choose a committee of five to nominate officers for the ensuing year.

Mr. Frank B. Walker will present a paper entitled, "Loading and Hauling Iron Ore from Mesabi Range to Lake Docks." The paper will be illustrated with lantern slides.

S. E. TINKHAM, *Secretary.*

PAPERS IN THIS NUMBER.

"Foundations of the New Buildings of the Massachusetts Institute of Technology, Cambridge, Mass." Charles T. Main and H. E. Sawtell.

"Concrete Materials and Design of the New Buildings of the Massachusetts Institute of Technology, Cambridge, Mass." Sanford E. Thompson.

CURRENT DISCUSSION.

Paper.	Author.	Published.	Discussion Closes.
"Water Powers of New England."	Henry I. Harriman.	Dec.	Feb. 10.

Contributors are hereby notified that proof will not be submitted to them for examination unless requested before the 10th of the month preceding the month of publication.

MINUTES OF MEETINGS.

CAMBRIDGE, December 19, 1917. — A regular meeting of the Boston Society of Civil Engineers was held this evening in the large lecture hall (Building No. 10), Massachusetts Institute of Technology, Cambridge, and was called to order by the President, George C. Whipple, at 7.45 o'clock.

There were 151 members and visitors present.

The record of the last meeting was read and approved.

The Secretary reported for the Board of Government that it had elected to membership, in the grade of member, Mr. Ashley Quincy Robinson.

The President announced the death of Henry A. Herrick, a member of the Society, which occurred on December 14, 1917, and by vote he was requested to appoint a committee to prepare a memoir. The President has named Mr. Charles T. Main as the committee.

The proposed amendment to By-Law 5, adopted at the November meeting, as printed in the November number of the JOURNAL of the Society, was adopted again as required by the By-Laws, 61 voting in favor and none against.

Before taking up the literary exercises, the President stated that arrangements had been made to exhibit the method used at the Institute for illustrating lectures, where a number of pieces of apparatus are employed. With the aid of a small railway track, several tables were pushed into the room at the speaker's desk, each of which had been properly fitted up in

adjoining laboratories in complete readiness for demonstrating the subjects to be treated at the lectures to be given the following day.

The President then called on Past President Charles T. Main, who read the first paper of the evening, entitled, "The Foundation of the New Technology Buildings." The paper was fully illustrated with diagrams and tables showing the results of borings and the records of pile driving.

The paper was discussed by Past President Desmond FitzGerald, Mr. Lewis M. Hastings and others.

The second paper presented was prepared by Sanford E. Thompson, entitled, "The Theoretical Design of the Structures of the New Technology Buildings." In the absence of the author the paper was read by Mr. Carl A. Funk, of Mr. Thompson's office. The paper was also illustrated with lantern slides. A short discussion followed.

On motion of Mr. Fernald the thanks of the Society were voted to the Massachusetts Institute of Technology for its courtesy in throwing open its buildings and laboratories for the inspection of members, and for the use of its commodious lecture room for the evening's meeting.

Adjourned.

S. E. Tinkham, *Secretary.*

Boston, December 5, 1917. — The regular meeting of the Sanitary Section of the Boston Society of Civil Engineers was held this evening, in the Society Library, Tremont Temple.

The meeting was called to order at 8 o'clock by the chairman, Frank A. Marston. The records of the November meeting were read and approved.

The first speaker of the evening, Mr. Stephen DeM. Gage, was introduced, and gave an illustrated talk on the subject of the sanitary conditions of swimming pools. The next speaker, Mr. S. K. Nason, physical director of the Brookline Municipal Gymnasium, described at length the Brookline Public Baths and the method of maintenance. Mr. Greenwood gave a brief description of the outdoor swimming pool in Gardner. Many

questions were asked by members and visitors, and brief remarks were made by Messrs. Blake, Clark, Whipple and Weston.

It was voted to extend the thanks of the Section to both Mr. Gage and Mr. Nason.

Forty-five members and visitors were present.

The meeting adjourned at 10.30.

HENRY A. VARNEY, *Acting Clerk.*

APPLICATIONS FOR MEMBERSHIP.

[January 10, 1918.]

THE By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission, and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of twenty (20) days from the date given.

EMERSON, JOHN MCNEIL, Brookline, Mass. (Age 30, b. Boston, Mass.) From June, 1908, to June, 1909, assistant superintendent at factory of Penn. Fireproofing Co., St. Marys, Pa., manufacturing hollow terra-cotta blocks; from 1909 to date, with Pennsylvania Tile and Cons. Co.; for past five years has been president of that company; work has consisted of advising on fireproof construction, redesigning and erection. Refers to J. P. Gallagher, J. S. Humphrey, Mark Linenthal, James F. Monaghan and J. T. Scully.

KILLION, LOUIS JOHN, Roxbury, Mass. (Age 33, b. Boston, Mass.) Graduate of Mass. Inst. of Technology, 1905, civil engineering course. From

1905 to 1906, with Lewis F. Shoemaker & Co., Pottstown and Philadelphia, Pa., on drafting, shopwork and field erection; from 1907 to 1912, with H. P. Converse & Co., Boston, on drafting, designing, estimating and field erection; from 1913 to November, 1917, with Drake Bros. Co. as superintendent in charge of Boston plant; is now with engineering department of Monks & Johnson, on Destroyer Plant at Squantum, Mass. Refers to E. P. Bliss, N. C. Burrill, J. E. Carty, H. T. Gerrish, C. M. Spofford and G. F. Swain.

Sauer, Fred Eugene, Jr., Everett, Mass. (Age 24, b. Everett, Mass.) Graduate of Mass. Inst. of Technology, 1914, civil engineering course, degree of B.S. During summer of 1914, rodman with N. Y., N. H. & H. R. R.; from August, 1914, to February, 1916, assistant engineer on subway construction with Public Service Comm., New York City; from February to August, 1916, structural draftsman with Post & McCord, New York City; from August, 1916, to November 1917, structural draftsman with Navy Dept., Washington, D. C.; from November, 1917, to date, assistant engineer with Metcalf & Eddy. Refers to C. F. Allen, C. B. Breed, H. P. Eddy and F. A. Marston.

Strand, Harry Lancaster, Brighton, Mass. (Age 38, b. Charlestown, Mass.) Student at Mass. Inst. of Technology from 1899 to 1901, architectural engineering course. From 1901 to 1903, with C. B. Lancaster Shoe Co. on construction work; from 1903 to 1909, with National Fire Proofing Co. on plans and redesign; from 1909 to date, with Pennsylvania Tile and Construction Co. as manager, in charge of planning buildings, redesigning and sales. Refers to R. D. Bradbury, J. P. Gallagher, C. R. Gow, A. C. Holt, J. S. Humphrey, Mark Linenthal and J. T. Scully.

LIST OF MEMBERS.

CHANGES OF ADDRESS.

Aspinwall, Thomas......................54 Stearns Rd., Brookline, Mass.
Beard, Cornelius................American Expeditionary Force, France.
Boas, Benjamin............care Monks & Johnson, Box 9, Atlantic, Mass.
Brown, William Augustine,
United States Naval Training Station, Bumkin Island, Mass. Div. 4, Dec. 3.
Cowles, Luzerne S....15 Dwight St., Coolidge's Corner, Brookline, Mass.
Cutting, George W., Jr.................10 Post Office Sq., Boston, Mass.
De La Haye, Elias F., Jr...............30 Waverly St., Roxbury, Mass.
Drummond, Capt. William W.,
care W. D. Caiger, 44 Manthorne Rd., West Roxbury, Mass.
Hubbard, Serg. Carl P.,
Co. D., 11th Engrs. (Rly), U. S. Expeditionary Force, France.
Hurd, Stephen P.....................512 Cutler Bldg., Rochester, N. Y.
Monaghan, Capt. James P.,
Ord. R. C., U. S. A., 1330 F St. N. W., Washington, D. C.

Richmond, Lieut. Carl G. . . . . E. O. T. C., Camp Lee, Petersburg, Va.
Sargent, Frank C. 201 Devonshire St., Boston, Mass.
Shaw, Capt. Arthur L. . . . . 301st Engrs., Camp Devens, Ayer, Mass.
Smith, Sidney . . . . care Hill & Ferguson, Camp Merritt, N. J.
Sumner, Merton R. . . . . Augustine Mills, Wilmington, Del.
Wade, Lieut. Clifford L. . . . . Hawthorne House, Wellesley Hills, Mass.
Waring, Major Charles T.,
care Construction Division, Signal Corps, Langley Field, Hampton, Va.
Wiggin, Capt. Thomas H.,
Engr. Corps., U. S. R., care Gen. Taylor, Amer. Expeditionary Force, France.
Wood, Carl W. . . . . 147 Milk St., Boston, Mass.
Wood, Capt. Leonard P. . . . American Expeditionary Force, via New York.
Worcester, Lieut. Robert J. H. . . . . 15 Lexington Rd., Concord, Mass.

DEATH.

Herrick, Henry A. . . . . December 14, 1917

EMPLOYMENT BUREAU.

The Board of Government maintains an employment bureau for the Society, to be a medium for securing positions for its members and applicants for membership, and also for furnishing employees to members and others desiring men capable of filling responsible positions.

At the Society room two lists are kept on file, one of *positions available* and the other of *men available*, giving in each case detailed information in relation thereto.

Men Available.

416. Age 53. Graduate of Mass. Inst. of Technology, 1886. Experience consists of one year with U. S. Geological Survey on topographic work; about twenty-five years with City of Boston in sewer, engineering and public works departments, chiefly on sewers, parks, bridges and special investigations; and about two years with prominent engineering firm on studies and designs for system of sewers and surface water drains and on bridge design. Prefers position in Boston or vicinity. Salary desired, $200 per month.

LIBRARY NOTES.

Recent Additions to the Library.

U. S. Government Reports.

Abrasive Materials in 1916. Frank J. Katz.

Annual Report of Governor of Panama Canal for 1916–17.

Barytes and Barium Products in 1916. James M. Hill.

Corsicana Oil and Gas Field, Texas. George Charlton Matson and Oliver Baker Hopkins.

Fuller's Earth in 1916. Jefferson Middleton.

Geology and Ore Deposits of Ely, Nevada. Arthur C. Spencer.

Geology of Massachusetts and Rhode Island. B. K. Emerson.

Geology of Navajo Country. Herbert E. Gregory.

Hydraulic-Mining Débris in Sierra Nevada. Grove Karl Gilbert.

Irvine Oil Field, Estill County, Kentucky. Eugene Wesley Shaw.

Mineral Resources of Kantishna Region, Alaska. Stephen R. Capps.

Mineral Resources of United States, 1915: Part I, Metals. H. D. McCaskey.

Mining in Lower Copper River Basin and Prince William Sound Region, Alaska. F. H. Moffit and B. L. Johnson.

Our Mineral Supplies: Fluorspar, by Ernest F. Burchard; Petroleum, by John D. Northrop.

Petroleum Withdrawals and Restorations Affecting the Public Domain, Issued between January 16 and September 30, 1916.

Pulpwood Consumption and Wood Pulp Production, 1916. Franklin H. Smith and R. K. Helphenstine, Jr.

Shorter Contributions to General Geology, 1916. David White.

Silica in 1916. Frank J. Katz.

Spirit Leveling in Nevada, 1897 to 1916, inclusive. R. B. Marshall.

Spirit Leveling in Ohio, 1898 to 1916, inclusive. R. B. Marshall.

Standard Forms for Specifications, Tests, Reports and Methods of Sampling for Road Materials.

Water-Supply Papers 389, 390, 404, 408, 425-B, 438.

State Reports.

New York. Annual Report of Public Service Commission for First District for 1915: Vols. I, Appendix F, and III.

Texas. Tables of Cubic Contents of Levee Embankments. Arthur Alvord Stiles.

Texas. Tables of Velocity of Water in Open Channels, derived from Kutter's Formula. Arthur Alvord Stiles.

Municipal Reports.

Boston, Mass. Annual Report of City Planning Board for 1916.

Boston, Mass. Annual Report of Transit Commission for 1916–17.

Chicago, Ill. Chicago's Financial Dilemma. Bureau of Public Efficiency.

Fitchburg, Mass. Annual Report of Water Commissioners for 1916.

Northampton, Mass. Annual Reports of City Officers for 1916.

Miscellaneous.

American Society for Testing Materials: Proceedings for 1917. Gift of L. C. Wason.

Canada, Dept. of Mines: Iron Ore Occurrences in Canada, Vol. I, by E. Lindeman and L. L. Bolton; Portfolio of Maps illustrating same.

National Lumber Manufacturers Association: The One-Story Schoolhouse Idea, by Fitzherbert Leather; Before Federal Trade Commission — Brief on behalf of National Lumber Manufacturers Association.

Reservoirs for Municipal Water Supply. Alfred D. Flinn. Gift of author.

State Sanitation, Vol. II. George Chandler Whipple. Gift of author.

LIBRARY COMMITTEE.

NEW ENGINEERING WORK.

(Under this head a brief description of new engineering work contemplated or under construction will be presented each month. Engineers and contractors are requested to send descriptions of their work to the Secretary, 715 Tremont Temple, Boston, before 1st of each month.)

Commonwealth of Massachusetts.— METROPOLITAN WATER AND SEWERAGE BOARD. — *Water Works.* — All of the poles and towers for the transmission line between the Wachusett and Sudbury power stations have been erected, and are now ready to receive the insulators and the copper conductors.

METROPOLITAN WATER AND SEWERAGE BOARD. — *Sewerage Works.* — Work in progress: Section 98, Wellesley Extension.

METROPOLITAN PARK COMMISSION. — *Old Colony Parkway.* — Construction of a temporary bridge across the Neponset River between Boston and Quincy is in progress; also construction of double siphon for water and gas under new channel.

BOSTON TRANSIT COMMISSION. — *Dorchester Tunnel.* — The interior finish of Broadway Station is about completed.

Work is progressing on the interior finish of the station at Andrew Sq., and work is in progress on the station for transfer of passengers from the surface cars to the tunnel below.

New York, New Haven & Hartford R. R. Co. — *South Boston Cut Improvement.* — Enlargement of South Boston Cut to Boston Freight Terminal, to accommodate four tracks instead of two, and reconstruction of eleven overhead highway bridges, so as to span four tracks instead of two, progressing. Excavation by steam shovel has advanced from westerly end of cut to West Fourth Street. Bridge abutments being constructed at West Sixth Street.

Vol. V JANUARY, 1918 No. 1

BOSTON SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

FOUNDATIONS OF THE NEW BUILDINGS OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY, CAMBRIDGE, MASS.

By Charles T. Main* and H. E. Sawtell,† Members Boston Society of Civil Engineers.

(Presented December 19, 1917.)

The purpose of this paper is to describe —

1st. The geological conditions found at the new site of the Massachusetts Institute of Technology and the methods used in determining the conditions.

2d. The foundations as built, and the reasons governing the types used.

3d. The pile tests, load tests and designs of portions of the foundations.

Our work on the foundations for these buildings was of a consulting nature, and all preliminary work up to and including the determination of total live and dead loads of superstructures going to the piles was performed by others.

The Stone & Webster Engineering Corporation's designs and construction work for all piling, footings, piers and walls, up to the underside of the first floor beams, were subject to our examination, supervision and approval.

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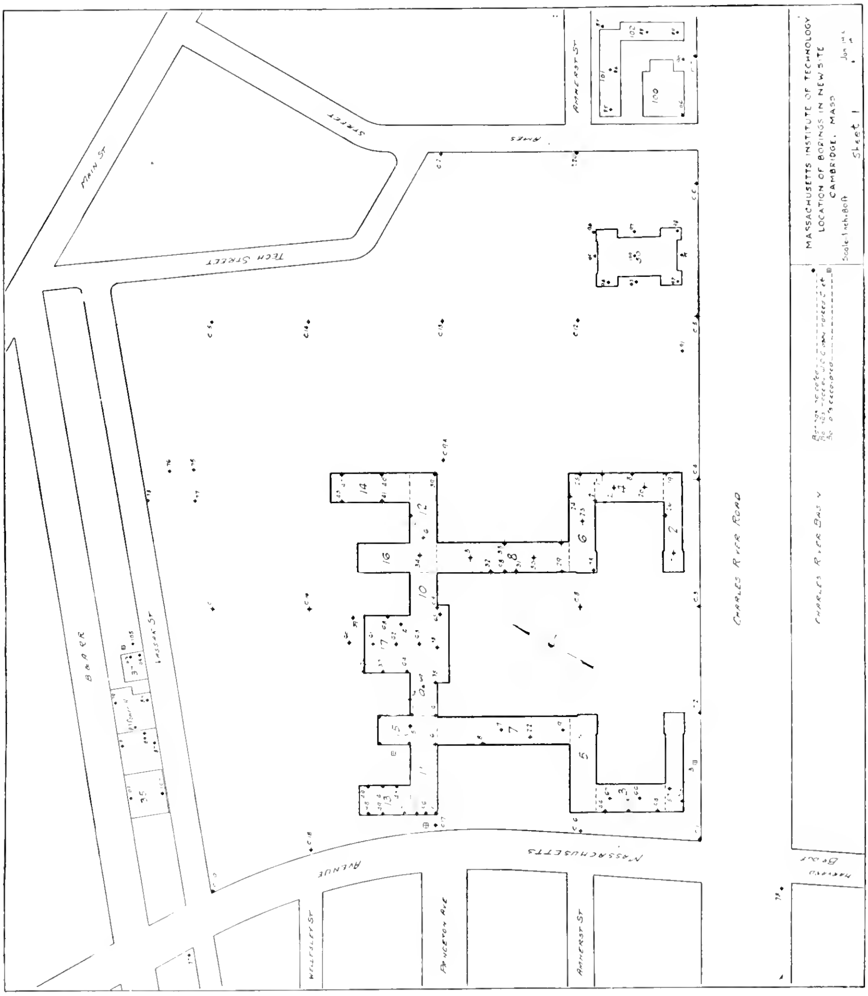
* Consulting Engineer, 201 Devonshire St., Boston.

† Structural Engineer, with Charles T. Main.

Note. Discussion of this paper is invited, to be received by W. L. Butcher, Editor, 715 Tremont Temple, Boston, before March 10, 1918, for publication in a subsequent issue of the Journal.



MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LOCATION OF BORINGS IN NEW SITE
CAMBRIDGE, MASS
Sheet 1
MAIN ST
TECH STREET
AMES
AMHERST ST
VASSAR ST
CHARLES RIVER ROAD
CHARLES RIVER BASIN
MASSACHUSETTS
AVENUE
WELLESLEY ST
PRINCETON AVE
AMHERST ST

FIG. 1.

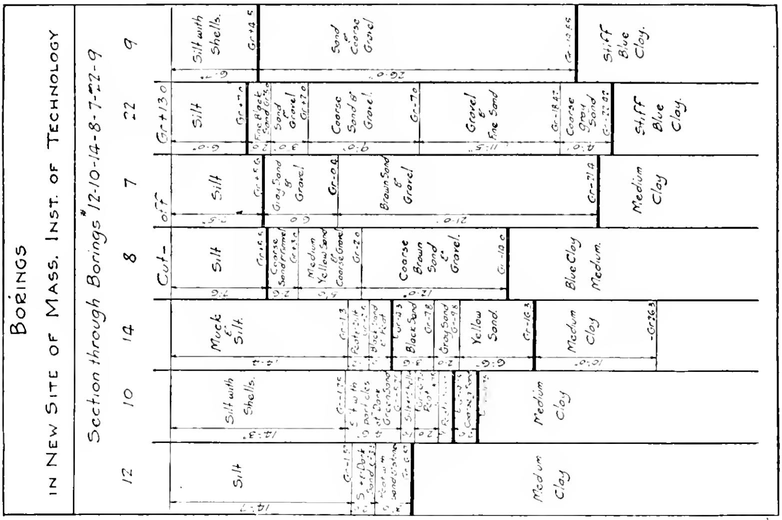

Borings
in New Site of Mass. Inst. of Technology
Section through Borings # 12-10-14-8-7-22-9

Fig. 3.

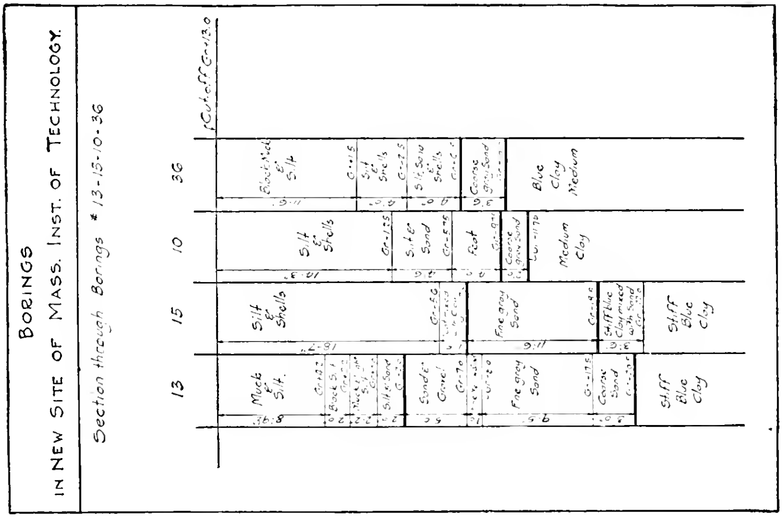

Borings
in New Site of Mass. Inst. of Technology.
Section through Borings # 13-15-10-36

Fig. 2.

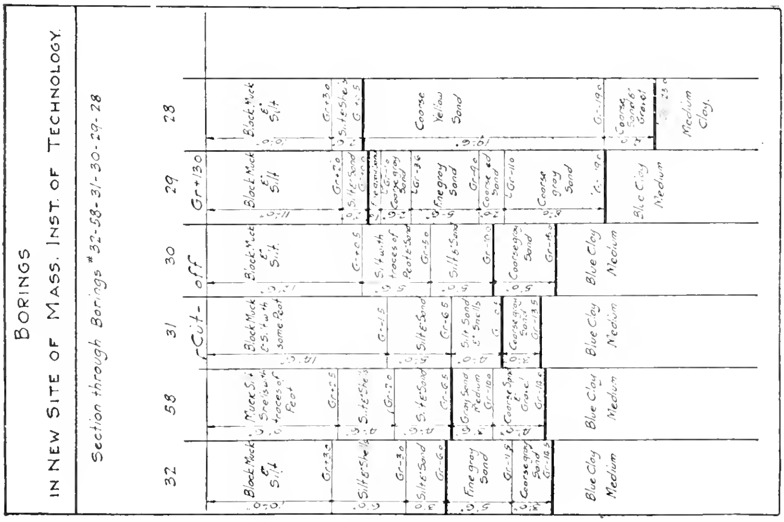

BORINGS
IN NEW SITE OF MASS. INST. OF TECHNOLOGY.
Section through Borings #32-58-31-30-29-28
-Cut- off

FIG. 4.

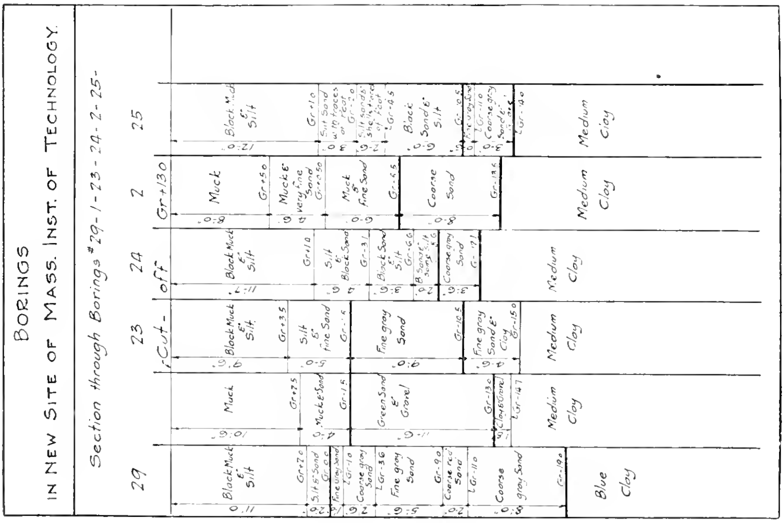

BORINGS
IN NEW SITE OF MASS. INST. OF TECHNOLOGY.
Section through Borings #29-1-23-24-2-25-
-Cut- off

FIG. 5.

In order to design foundations for the new buildings, it was necessary to make an unusual amount of study of the soil and rock underlying the site and the supporting capacity of the same.

In July, 1913, Prof. W. O. Crosby submitted a report on the site. This report was based chiefly on the results obtained from borings in and just outside the limits of the new site.

This report shows that the bed rock is found at a depth of 120 ft. to 135 ft. from the surface, and appears to be quite level. The materials overlying the bed rock include, in succession, bowlder clay varying in thickness from a few feet to 25 or 30 ft.; blue clay with a normal thickness of 60 to 100 ft.; glacial gravel ranging from nothing to 35 ft. in thickness; silt from 0.0 ft. to 18 ft. in thickness; peat, very thin and showing in a few places only, and the artificial filling at the surface varying in thickness from a few to 15 or 20 ft.

The twenty-one borings made by Professor Crosby were rather widely separated, and it was found, soon after actual work was begun, that the character and surface levels of the glacial deposit changed frequently so that it was thought necessary to make additional borings one hundred and six in number, on or near the sites of the different buildings.

The locations of both sets of borings are shown on the accompanying Fig. 1, together with some of the cross sections, Figs. 2, 3, 4, 5 and 6, which show the varying character of the upper soil which is located under some of the buildings.

The top of the glacial gravel was found to be at all levels varying from 6 ft. to 26 ft. below the cut-off grade of piles, and the thickness varied from nothing to 35 ft. In a considerable part of one or two buildings, no glacial gravel was found.

Three test pits were dug to a depth of about 22 ft., in order to check up the wash borings. Eleven concrete piles and eighty-one wooden test piles were driven, while twenty-five piles of all kinds were load tested for the purpose of further determining the character, resistance and bearing power of the substrata.

A considerable part of Professor Crosby's report is devoted to the cause of the observed settlements of structures which surround the new site. He states that it is his opinion that the

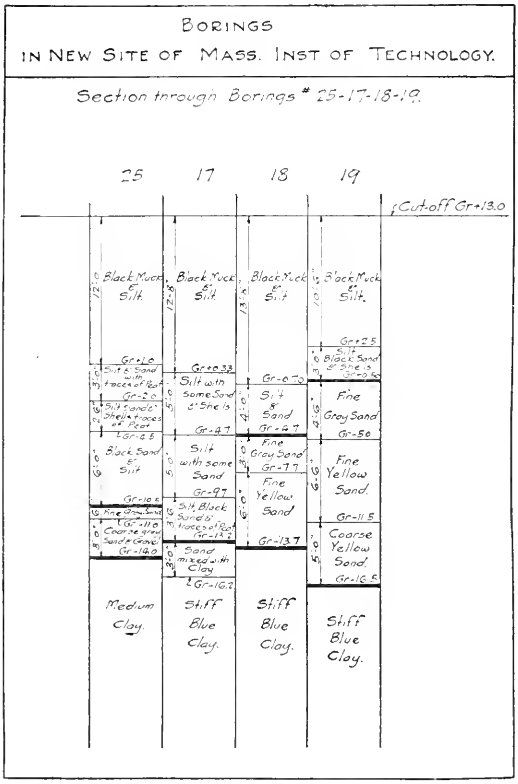


FIG. 6

settlements are only such as would be expected from a study of their foundations and the underlying earth conditions, and that it is his belief that had the foundations of these structures been carried down to or supported on the glacial gravel, they would not have settled to any appreciable extent.

The term "glacial gravel" is understood to mean that deposit immediately found above the clay, which varies in character from fine sand to coarse gravel. As it is found generally to be well compacted and comparatively near the surface, it was decided to support the foundations upon it wherever practicable.

The clay found under the glacial gravel is of remarkably

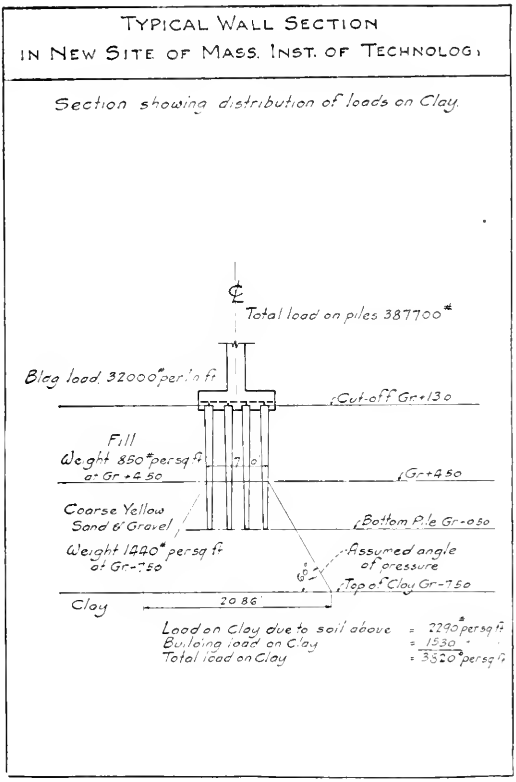


FIG. 7.

uniform character, of little plasticity, and — to use Professor Crosby's words — "It is probable that in its normal condition in the ground all of the clay is devoid of excess moisture and fairly to be described as stiff."

It has been assumed, however, that if settlement occurs, it will be in the clay, and in order to reduce this settlement to a minimum it was decided to spread the building loads over the glacial gravel as much as practicable, which in turn would still further distribute the loads over the clay bed.

In order to provide for a wide distribution of load on the gravel in the most uniform manner, with a resulting low pressure per square foot, it was decided to use a large number of

wood piles, each sustaining a relatively small load, rather than a few heavily loaded piles. See Fig. 7.

This shows the piling under a footing resting in 12 ft. of gravel or sand, and the assumed spreading of the load accomplished by means of 60 degree angles of distribution, with the horizontal. The building loads in this case were reduced to about three fourths of a ton, on the surface of the clay, which would be in addition to the load of the overburden already found on the site in place.

The decision that heavy, concentrated loads were to be avoided precluded the use of concrete piles for this particular work.

It was also found that wood piling would be considerably less expensive than concrete piling, due to the fact that the permanent water level was high, making it unnecessary to place any concrete in addition to that required for the foundations to meet the heads of the wood piling, also to the fact that large piles do not prove economical where flexibility is required for light as well as heavy loads.

Interesting tests were made, however, on concrete piles of both the Simplex and Raymond types.

Fig. 8 is a plan of the site, with the buildings in outline, showing the location of most of the important test piles; and near the location of each pile has been placed a letter, in addition to its number, to designate its kind, — "S" meaning spruce, "O" for oak, "P" for southern pine, etc.

Spruce piles from Nos. 1 to 30, inclusive, were driven from September 8, 1913, to September 25, 1913; spruce piles Nos. 31, 32, 33 and 34 were driven on December 2, 1913; oak piles 1 to 16 inclusive were driven on December 2, 3, 4 and 5, 1913; and piles in Building No. 17 were driven in September and October of 1914.

Other piles were driven and tested as noted in Tables 1, 2 and 3.

The factor of safety at $\frac{1}{4}$-in. settlement was arrived at by dividing the load carried at $\frac{1}{4}$-in. settlement by the load carried at $\frac{1}{16}$-in. settlement.

If the safety factor was not as high as $2\frac{1}{2}$, then the tonnage

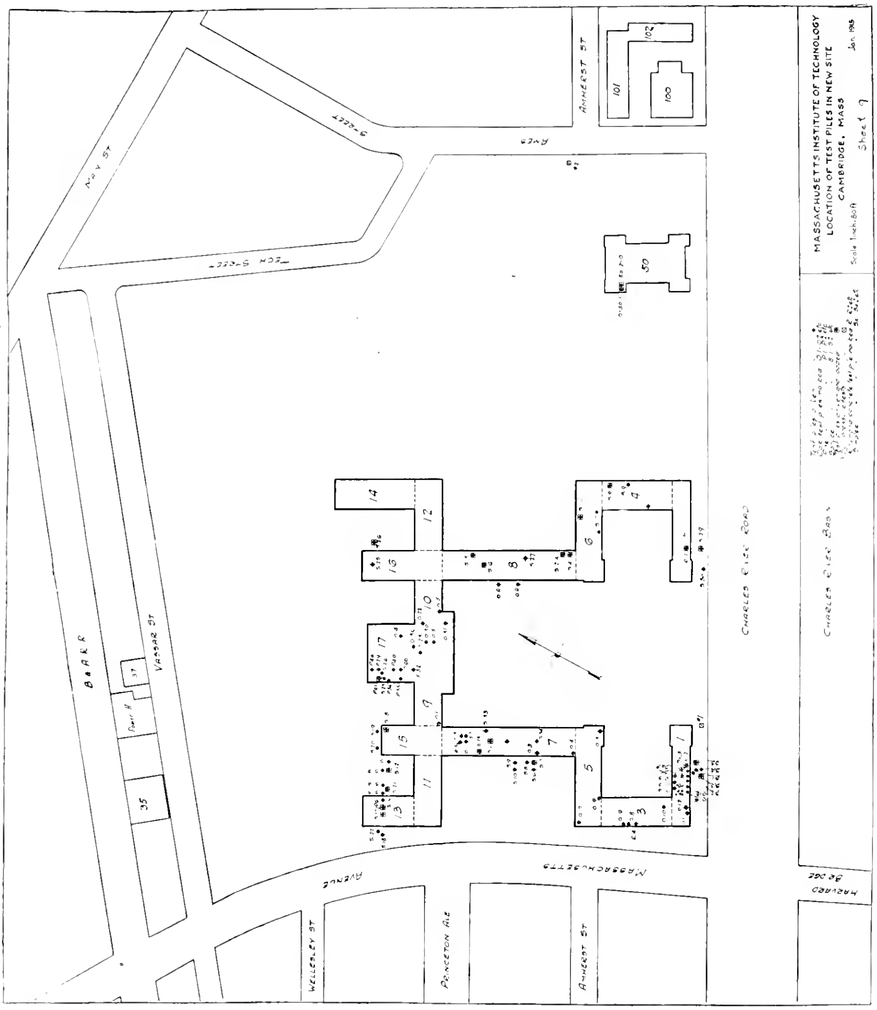

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LOCATION OF TEST PILES IN NEW SITE
CAMBRIDGE, MASS
Sheet 9
CHARLES RIVER ROAD
CHARLES RIVER BASIN
MASSACHUSETTS AVENUE
HARVARD BRIDGE
AMHERST ST
PRINCETON AVE
WELLESLEY ST
VASSAR ST
TECH STREET
B & A R R

FIG. 8

TABLE 1.

Test Piles in New Site of Massachusetts Institute of Technology.

Group A. Spruce.

Identity.		Length of Pile.	Embedment.		Surface Grades.		Ave. Drop Last Blows 2,300-lb. Hammer.	Ave. Pen. Last 3 Blows.	Formula Load. Tons.	Test Load at $\frac{1}{16}''$ Settlement.	Factor of
Bldg. No.	Pile No.		Sand.	Clay.	Sand.	Clay.					
← Near No. 1 →	1	31′ 7″	?	0	+3.0	....	9′ 9″	3″	...	..	.
	2	32′ 9″	6′ 6″	0	+6.25	....	7′ 2″	$\frac{1}{3}''$	...	...	.
	3	17′ 0″	3′ 9″	0	+4.01	....	9′ 8″	$\frac{1}{3}''$	16.70	6.0*	1.
	4	20′ 0″	1′ 6″	0	+5.30	....	4′ 10″	$\frac{5}{16}''$	...	...	.
	5	20′ 0″	5′ 1″	0	+5.13	....	6′ 2″	$\frac{5}{8}''$	8.70	7.0*	1.
← Near No. 7 →	6	20′ 0″	3′ 9″	0	+6.66	....	9′ 6″	$\frac{7}{8}''$	...	...	.
	7	20′ 0″	5′ 9″	0	+6.29	....	10′ 0″	$1\frac{3}{4}''$	8.40	3.1 tons	1.
	8	30′ 0″	8′ 9″	0	+5.51	....	6′ 0″	1″	...	...	.
	9		4′ 10″	0	+4.86	....	11′ 10″	$3\frac{1}{4}''$	6.50	...	.
	10	30′ 0″	10′ 11″	0	+5.23	....	7′ 7″	$\frac{1}{4}''$	13.90	...	.
Near 15	11	20′ 2″	2′ $8\frac{1}{2}''$	0	−0.14	−12.58	8′ 0″	2″	7.80	...	.
Near 11	12	30′ 0″	12′ 0″	0	−0.70	−12.00	9′ 0″	2″	6.90	3.75 ±	3.
Near 11	13	36′ 0″	8′ 0″	5.75′	−5.00	−13.0	9′ 0″	$1\frac{1}{4}''$	9.20	...	.
Near 11	14	36′ 0″	20.75		−0.25	....	5′ 0″	$\frac{1}{3}''$	...	...	.
Near 13	15	32′ 0″	13.67		−2.67	....	10′ 2″	2″	...	...	.
13	16	36′ 0″	18.75′	0	+3.53	−15.50	11′ 2″	2″	8.50+	...	.
13	17	36′ 0″	15.50′	1.56′	−1.50	−17.0	10′ 0″	2″	7.70	9.0*	[illegible]
Near 13	18	36′ 0″	16.30′	1.0′	−1.25	−17.5	10′ 5″	$1\frac{1}{2}''$	9.66	...	.
Near 15	19	36′ 0″	0	13.43′	0	−6.57	11′ 0″	5″	4.20	...	.
Near 15	20	45′ 0″	6.0′	22.33′	−6.58	−12.5	10′ 6″	$3\frac{1}{3}''$	...	...	.
Near 11	21	44′ 0″	14.5′	12.5′	−1.0	−15.5	11′ 0″	$1\frac{1}{2}''$	10.1	Emb	ed
Near 13	22	45′ 0″	12.0′	13.45′	−2.25	−14.25	10′ 5″	1″	12.0	...	.
17	23	36′ 0″	8.0′	9.37′	−3.0	−11.0	6′ 4″	$1\frac{1}{3}''$	...	...	.
17	24	44′ 0″	10.0′	15.20′	−2.0	−12.0	9′ 2″	$1\frac{1}{4}''$	9.40	...	.
Near 16	25	45′ 0″	13.25′	14.50′	+2.25	−11.0	10′ 9″	$\frac{3}{4}''$	14.3	...	
Near 12	26	30′ 0″	11.8′	1.95′	+1.40	−10.4	10′ 6″	2″	8.05	11.5	
Near 8	27	41′ 0″	5′ 9″	3′ 9″	−5.75	−11.50	10′ 9″	$1\frac{5}{16}''$	10.7	...	
6	28	42′ 0″	13′ 6″	6′ 4″	−1.50	−15.00	8′ 6″	$\frac{3}{5}''$	14.0	...	
Near 2	29	30′ 0″	10′ 0″	0′ 6″	+1.30	−8.60	6′ 6″	$\frac{5}{8}''$	9.2	9*	2
Near 2	30	40′ 0″	13′ 6″	0	−0.80	−18.0	13′ 6″	$\frac{5}{8}''$	20.0	...	
7	31	25′ 0″	11′ $7\frac{1}{2}''$	0	+3.80	....	7′ 0″	1″	8.0	...	
7	32	34′ 0″	17′ 10″	0	+3.10	....	5′ 0″	$\frac{1}{2}''$	7.6	...	.
7	33	30′ 0″	10′ 0 ±	0	+4.40	....	5′ 0″	$\frac{1}{2}''$	7.7	...	
7	34	18′ 0″	5′ 4″	0	+5.60	....	5′ 0″	1″	5.7	...	

* Found by interpolation.

TABLE 1. — *Continued.*

TEST PILES IN NEW SITE OF MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

A. Spruce.

alue for F. S. of 2.5 or More.	Character.		Formula Values at Other Embedments.	Reported Condition when Driven.	Actual Condition when Pulled.	Remarks.
	Sand.	Clay.				
...	Gravel	....	....	Broken	Broken	.....
...	Gravel	....	....	Broomed	Broomed	.....
...	Gravel	....	....	Good pile	Broken and Broomed	.....
...	Gravel	....	....	Hard driving	Broken	.....
...	Gravel	....	....	Uniform driving	Broken and broomed	.....
...	Gravel	....	....	Broomed	Broken and broomed	.....
...	Gravel	....	....	Uniform driving	Broken and broomed	.....
...	Gravel	....	....	Broken	....	.....
...	Gravel	....	....	Uniform driving	Broken	.....
...	Gravel	....	....	Hard but Uniform driving	Broken	8″ crust
...	Sand	....	....	....	....	.....
4.5	Fine sand	....	10 tons @ 10.5′	Uniform driving	OK	Early settlements appear excessive
...	....	....	10.3 tons @ 7.0′	Uniform driving	....	.....
...	....	....	8.2 tons @ 9.0′	Follower	used	.....
...	....	....	8.0 tons @ 12.5′	Follower	used	.....
...	Sand	....	8.7 tons @ 12.0′	Easy driving	....	.....
ns@2.50	Fine sand	....	8.6 tons @ 12.0′	Easy driving	OK	.....
...	Sand	....	....	Uniform driving	....	.....
...	0	....	....	Easy driving	....	.....
...	....	....	....	Follower	used	.....
ettlemen	t readings	of load te	st, doubtful.	....	....	.....
...	Sand	....	11.4 tons @ 12.0′	....	....	.....
...	....	....	7.5 tons @ 6.0′	Follower	used	.....
...	....	....	9.0 tons @ 7.0′	Uniform driving	....	.....
...	....	....	....	....	....	.....
1.2	Sand	Blue medium	9.2 tons @ 10.0′	4.6′ of clay and	shells abov	e the sand.
...	Sand	....	....	....	....	.....
...	Sand	....	12.2 tons @ 10.0′	Uniform driving	....	.....
8	Coarse Sand	Clay and Gravel	11.2 tons @ 10.0′	Uniform driving	Tip slightly broomed around edges	Early settlement readings in question
...	Sand	....	14.0 tons @ 10.0′	Probably broomed	....	.....
...	Fine sand	....	....	....	Pulled OK	.....
...	Fine sand	....	9.1 tons @ 11′ 6″	....	Pulled OK	.....
...	Fine sand	....	9.1 tons @ 9′ 0″	....	OK	.....
...	Fine sand	....	8.0 tons @ 1′ 0″	....	OK	.....
			5.8 tons @ 2′ 0″			

TABLE 2.

TEST PILES IN NEW SITE OF MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

GROUP B. Oak Piles.

Identity.		Length of Pile.	Embedment.		Surface Grades.		Ave. Drop Last Blows 2300-lb. Hammer.	Ave. Pen. Last 3 Blows.	Formula Load. Tons.	Test Load at $\frac{1}{16}$″ Settlement.	Factor of Safety at ½″
Bldg. No.	Pile No.		Sand.	Clay.	Sand.	Clay.					
7	1	20′ 6″	7′ 6½″	...	4.0	....	8′ 0″	1½″	7.1	...	..
7	2	20′ 8″	9′ 8½″	...	6.0	....	6′ 0″	⅞″	7.3	...	..
7	3	15′ 3″	4′ 10″	...	6.6	....	5′ 0″	½″	7.7	...	..
5–7	4	15′ 0″	4′ 11″	...	5.9	....	6′ 0″	1⅜″	5.6	...	..
5	5	20′ 9″	10′ 1″	...	6.2	....	5′ 0″	⅞–1″	6.2	...	..
5	6	20′ 8″	8′ 7″	...	9.9	....	5′ 0″	¼–⅜″	9.2	...	..
5	7	15′ 0″	7′ 5½″	...	9.4	....	5′ 0″	¼–⅜″	9.2	...	..
3	8	15′ 0″	2′ 0″	...	3.4	....	6′ 0″	⅞″	7.5	...	..
3	9	22′ 0″	9′ 0″	...	4.4	....	10′ 0″	1.2″	10.7	...	..
3–1	10	20′ 0″	10′ 0″	...	6.5	....	10′ 0″	1½″	9.2	...	..
1	11	20′ 0″	3′ 4½″	...	0.0	....	5′ 0″	1.1″	5.4	...	..
1	12	24′ 6″	8′ 9½″	...	2.1	....	10′ 0″	1.2″	10.5	...	..
1	13	20′ 9″	10′ 3½″	...	5.7	....	10′ 0″	1.25″	10.2	...	..
1	14	20′ 7″	10′ 1″	...	6.3	−2.5	5′ 0″	⅜″	8.5	...	..
1	15	20′ 0″	7′ 7″	...	6.2	....	8′ 0″	¼″	14.7	...	..
1	16	18′ 6″	6′ 10″	...	6.0	....	5′ 0″	¼″	9.2	...	..

TABLE 2. — *Continued.*

TEST PILES IN NEW SITE OF MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

B. Oak Piles.

Value for F. S. of 2.5 or More.	Character.		Formula Values at Other Embedments.	Reported Condition when Driven.	Actual Condition when Pulled.	Remarks.
	Sand.	Clay.				
...	....	...	7.6 tons @ 3′ 0″	...	Pulled OK	Easy driving
...	..	...	9.1 tons @ 2′ 0″	...	....	Easy driving
...	..	....	7.9 tons @ 2′ 0″	.	...	Easy driving
...	..	....	7.0 tons @ 2′ 6″	.	..	Easy driving
...	..	....	6.2 tons @ 2′ 0″		.	Easy driving
...	..	..	9.2 tons @ 8′ 6″		...	.....
....	..	...	....			.....
....		....	....			Easy driving
....		..	11.0 tons @ 5′ 0″		.	.....
....	.	...	....	.	..	.....
....		..	....	..	.	Easy driving
....	.	..	11.5 tons @ 2′ 9″	...	.	.....
....		.	10.2 tons @ 3′ 0″	.	....	.....
....		..	12.7 tons @ 3′ 0″	....	Point probably in clay	Easy driving
....	.	.	11.5 tons @ 2′ 0″	....	....	.....
			12.3 tons @ 4′ 0″			
....	.	....	10.5 tons @ 2′ 0″	..	...	.....

TABLE 3.

TEST PILES LOADED IN NEW SITE OF MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

GROUP C.

Identity.		Length of Pile.	Embedment.		Surface Grades.		Ave. Drop Last Blows of Hammer.	Ave. Pen. Last 3 Blows.	Formula Load. Tons.	Test Load at $\frac{1}{16}''$ Settlement.	Factor of Safety at $\frac{1}{4}''$
Bldg. No.	Pile No.		Sand.	Clay.	Sand.	Clay.					
8	14a 5	35′ 10″	11′ 6″	7′ 3″	−1.5	−13.0	2600 @ 10′	$3\frac{3}{4}''$	5.50	5.5 tons*	6.5
8	2a 4	30′ 0″	13′ 2″	0′ 6″	−1.5	−14.7	2150 @ 10′	$2\frac{1}{2}''$	6.14	7 tons	1.75
8	12d 6	42′ 6″	11′ 6″	15′ 4″	−1.5	−13.0	2600 @ 10′	3″	6.50	9 tons*	4.0-
8	2a 2a	35′ 9″	12′ 6″	6′ 2″	−1.5	−14.5	2150 @ 10′	2″	7.16	10 tons	2.3
6	12g 12	45′ 0″	1′ 6″	18′ 5″	. . .	. . . .	2600 @ 10′	$3\frac{3}{8}''$	5.90	15.43 tons	2.0
4	11a 6	50′ 0″	0	21′ 3″	0	−13.2	2580 @ 10′	$4\frac{3}{4}''$	4.50	12.80 tons	1.63
15	10a 18	42′ 6″	0	23′ 0″	0	−6.6	2300 @ 10′	3″	5.80	12.88 tons	1.6
7	13g 13	14′ 9″	5′ 10″	0	+5.60	0	2300 @ 10′	$2\frac{1}{8}''$	7.40	8.0 tons*	1.75
7	11d 2	15′ 6″	5′ 7″	0	+5.60	0	2300 @ 10′	$1\frac{5}{8}''$	8.80	9.0 tons*	1.5
Near 15	12	30′ 0″	12′ 0″	0	−0.7	−12.6	2300 @ 9.0′	2″	6.9	3.75 ± tons	3.0
Near 13	17	36′ 0″	15′ 6″	1.56′	−1.5	−17.0	2300 @ 10.0′	2″	7.7	9.0 tons*	3.0
Near 11	21	44′ 0″	14′ 6″	12.60′	−1.0	−15.5	2300 @ 11.0′	$1\frac{1}{2}''$	10.1	Embed	men
Near 16	26	30′ 0″	11′ 10″	1.95′	+1.4	− 10.4	2300 @ 10.5′	2″	8.05	11.50 tons	2.4
Near 2	29	30′ 0″	10′ 0″	0.5′	+1.3	−8.6	2300 @ 6.5′	$\frac{5}{8}''$	9.02	9.0 tons*	2.2
17	n8 41	46′ 0″	5′ 6″	20.75′	−3.50	−9.0	2550 @ 10.0′	2″	8.50	9.8 tons*	2.75
50	50–1	29′ 9″	1′ 6″	0	−7.99	−12.49	2600 @ 10.0′	$1\frac{1}{2}''$	10.40	7.40	2.3
50	50–2	30′ 9″	1′ 6″	0	−6.75	−11.25	2600 @ 10.0′	3″	6.50	7.36	2.2

* Found by interpolation.

TABLE 3. — *Continued.*

TEST PILES LOADED IN NEW SITE OF MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

UP C.

Allowable Value for F. S. of 2.5 or More.	Character.		Formula Values at Other Embedments.	Reported Condition when Driven.	Actual Condition when Pulled	Remarks.
	Sand.	Clay.				
7.5 tons	Coarse and medium	Medium	....	....	OK	Allowable value limited by settlement
5.0 tons	Sand and fine gravel	Medium	....	....	....	.....
2.0 tons	Coarse and medium	Medium	....	....	....	.....
9.0+ tons	Coarse and medium	Medium	....	....	....	.....
2.0 tons	....	Medium	Redriven	value	....	13.90
8.4 tons	0	Stiff	Redriven	value	....	11.50
8.2 tons	0	Medium	....	....	....	.....
6.0 tons	Sand Gravel	0	....	....	Pulled OK	.....
5.6 tons	Sand Gravel	0	....	....	Pulled OK	.....
4.5 tons	Fine sand	....	10 tons @ 10.5′	Uniform driving	Pulled OK	Early settlements appear excessive
11.0 tons @ 2.5	Fine sand	....	8.6 tons @ 12.0′	Easy driving	OK	.....
ubtful and	settlement	readings	of load test dou	btful.	....	.....
11.2 tons	Sand	Blue medium	9.2 tons @ 10.0′	4′ 6″ of clay and	shells abov	e the sand.
8.0 tons	Coarse sand	Clay and gravel	11.2 tons @ 10.0′	Uniform driving	Tip slightly broomed around edges	Early settlement readings in question
10.8 tons	Fine and coarse	Medium blue	Uniform increas	e in tonnage in c	lay.	.....
6.88 tons	Medium	0	....	....	Not pulled	Driven butt down
6.60 tons	Medium	0	....	....	Not pulled	Driven tip down

TABLE 4.

TEST OF PILES IN NEW SITE OF MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

Identity.	Character.	Total Length in Ground (Feet).	Length in Sand, Gravel or Clay (in Feet).	Tip Diameter (in Inches.)	Weight of Hammer (Lbs.).	Fall of Hammer (in Feet).	Penetration, Last Blow (in Inches).	Formula Value.	Test Load (Pounds).	Settlement (Inches).
14a			Sand							
5	Spruce	32.8	11.5	5	2 600	10	$3\frac{3}{4}$		6 990	0
8			Clay						11 970	$\frac{1}{8}$
			7.25						26 390	$\frac{1}{8}$
									31 640	$\frac{5}{32}$
									36 900	$\frac{5}{32}$
									53 641	$\frac{5}{32}$
									66 504	$\frac{5}{32}$
									72 925	$\frac{7}{32}$
									77 403	$\frac{25}{32}$
2a			Sand							
4	Spruce	27.7	13.2	6	2 150	10	$2\frac{1}{2}$		13 920	$\frac{1}{32}$
8			Clay						18 690	$\frac{7}{32}$
			0.5						24 510	$\frac{1}{4}$
									29 860	$\frac{17}{64}$
12d			Sand							
6	Spruce	40.9	11.5	6	2 600	10	3		7 090	0
8									14 350	$\frac{1}{16}$
			Clay						20 388	$\frac{3}{32}$
			15.33						25 241	$\frac{3}{32}$
									29 861	$\frac{1}{8}$
									35 068	$\frac{1}{8}$
									45 068	$\frac{1}{8}$
									59 161	$\frac{1}{8}$
									65 509	$\frac{1}{8}$
									70 686	$\frac{3}{16}$
									75 228	$\frac{1}{4}$
									80 108	$\frac{5}{16}$
									84 834	$\frac{5}{16}$
									89 814	$\frac{7}{16}$
2a			Sand							
2a	Spruce	32.8	12.5	$5\frac{1}{2}$	2 150	10	2		8 990	0
8			Clay						13 760	$\frac{3}{64}$
			6.2						20 030	$\frac{1}{16}$
									28 210	$\frac{5}{64}$
									34 200	$\frac{11}{64}$
									40 040	$\frac{11}{64}$
									45 898	$\frac{19}{64}$
									51 000	$\frac{19}{64}$
									58 070	$\frac{19}{64}$
									62 361	$\frac{19}{64}$

TABLE 5.

TEST OF PILES IN NEW SITE OF MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

Identity.	Character.	Total Length in Ground (Feet).	Length in Sand, Gravel or Clay (in Feet).	Tip Diameter (in Inches).	Weight of Hammer (Lbs.).	Fall of Hammer (in Feet).	Penetration Last Blow (in Inches).	Formula Value.	Test Load (Pounds).	Settlement (Inches).
12g	...	...	Sand	...	...	...	...	...	...	...
12	Spruce	43.1	1.5	5	2 600	10	$3\frac{3}{8}$	...	7 889	$\frac{1}{64}$
6	...	...	Clay	...	...	...	...	...	16 629	$\frac{1}{32}$
...	...	...	18.5	...	...	...	...	...	21 515	$\frac{3}{64}$
...	...	...	...	...	...	...	...	...	25 993	$\frac{3}{64}$
...	...	...	...	...	...	...	...	...	30 866	$\frac{1}{16}$
...	...	...	...	...	...	...	...	...	39 439	$\frac{3}{32}$
...	...	...	...	...	...	...	...	...	44 919	$\frac{7}{64}$
...	...	...	...	...	...	...	...	...	48 521	$\frac{9}{64}$
...	...	...	...	...	...	...	...	...	53 771	$\frac{3}{16}$
...	...	...	...	...	...	...	...	...	59 161	$\frac{13}{64}$
...	...	...	...	...	...	...	...	...	63 951	$\frac{1}{4}$
...	...	...	...	...	...	...	...	...	68 677	$\frac{9}{32}$
...	...	...	...	...	...	...	...	...	73 597	$\frac{5}{16}$
...	...	...	...	...	...	...	...	...	78 547	$\frac{19}{32}$
...	...	...	...	...	...	...	...	...	83 547	$\frac{5}{8}$
...	...	...	...	...	...	...	...	...	9 146	0
11a	...	...	Sand	...	...	...	...	...	19 135	$\frac{1}{32}$
6	Spruce	46.5	0	5	2 580	10	$4\frac{3}{4}$	...	25 681	$\frac{1}{16}$
4	...	...	Clay	...	...	...	...	...	30 687	$\frac{1}{8}$
...	...	...	21.25	...	...	...	...	...	35 567	$\frac{5}{32}$
...	...	...	...	...	...	...	...	...	41 810	$\frac{3}{16}$
...	...	...	...	...	...	...	...	...	47 017	$\frac{3}{8}$
...	...	...	...	...	...	...	...	...	52 017	$\frac{3}{8}$
...	...	...	...	...	...	...	...	...	56 462	$\frac{7}{16}$
...	...	...	...	...	...	Pile	tilted	...	61 475	$\frac{9}{16}$
...	...	...	...	...	...	...	...	...	66 485	$\frac{6}{16}$
...	...	...	...	...	...	...	...	...	70 554	$\frac{19}{32}$
...	...	...	...	...	...	...	...	...	74 619	$\frac{5}{8}$
...	...	...	...	...	...	...	...	...	74 619	$\frac{25}{32}$
...	...	...	...	...	...	...	...	...	77 429	$\frac{27}{32}$
...	...	...	...	...	...	...	...	...	77 429	$1\frac{1}{8}$

TABLE 6.

Test of Piles in New Site of Massachusetts Institute of Technology.

Identity.	Character.	Total Length in Ground (Feet).	Length in Sand, Gravel or Clay (in Feet).	Tip Diameter (in Inches).	Weight of Hammer (Lbs.).	Fall of Hammer (in Feet).	Penetration Last Blow (in Inches).	Formula Value.	Test Load (Pounds).	Settlement (Inches).
10a	...	...	Sand	...	...	...	..	..	7 318	0
18	Spruce	42.1	0	$5\frac{1}{2}$	2 300	10	3	..	12 040	$\frac{1}{64}$
15	...	...	Clay	...	...	...	..	..	17 237	$\frac{1}{32}$
...	...	...	23.0	...	...	...	..	..	21 467	$\frac{1}{32}$
...	...	...	...	...	...	...	..	..	25 697	$\frac{1}{16}$
...	...	...	...	...	...	...	..	..	30 377	$\frac{7}{64}$
...	...	...	...	...	...	...	..	..	36 430	$\frac{1}{8}$
...	...	...	...	...	...	...	..	..	41 069	$\frac{1}{4}$
...	...	...	...	...	...	...	..	..	46 297	$\frac{21}{64}$
...	...	...	...	...	...	...	..	..	50 961	$\frac{21}{64}$
...	...	...	...	...	...	...	..	..	55 071	$\frac{21}{64}$
...	...	Pile began to split vertically					..	..	59 190	$\frac{3}{8}$
...	...	...	...	...	...	...	..	..	6 570	0
13g	...	...	Sand	...	...	...	..	..	11 860	$\frac{1}{32}$
13	Spruce	12.8	5.8	6	2 300	10	$2\frac{1}{8}$	..	21 300	$\frac{5}{32}$
7	...	...	Clay	...	...	...	..	..	26 480	$\frac{5}{32}$
...	...	...	0	...	...	...	..	..	32 423	$\frac{5}{16}$
...	...	...	...	...	...	...	..	..	37 560	$\frac{3}{8}$
...	...	...	...	...	...	...	..	..	42 960	$\frac{3}{8}$
...	...	...	...	Pile tilted		...	..	..	......	..
...	...	...	Sand	...	...	...	..	..	7 653	0
11d	Spruce	12.6	5.6	$5\frac{1}{2}$	2 300	10	$1\frac{5}{8}$	..	12 326	$\frac{1}{64}$
2	...	...	Clay	...	...	...	..	..	16 500	$\frac{3}{64}$
7	...	...	0	...	...	...	..	..	21 710	$\frac{5}{32}$
...	...	...	...	...	...	...	..	..	26 704	$\frac{5}{32}$
...	...	...	...	...	...	...	..	..	31 707	$\frac{7}{16}$
...	...	...	...	...	...	...	..	..	37 892	$\frac{7}{16}$
...	...	...	...	...	...	...	..	..	42 721	$\frac{7}{16}$
...	...	...	...	...	...	...	..	..	48 660	$\frac{3}{4}$
...	...	...	...	...	...	...	..	..	53 797	$\frac{3}{4}$
...	...	...	...	...	...	...	..	..	59 197	$\frac{49}{64}$
...	...	...	...	...	...	...	..	..	64 381	$\frac{13}{16}$
...	...	...	Sand	...	...	...	..	..	.. ...	..
n8	Pine	43.85	5.5	$6\frac{1}{2}$	2 550	10	2	..	11 381	0
41	...	...	Clay	...	...	...	..	..	19 730	$\frac{3}{64}$
17	...	...	20.75	...	...	...	..	..	23 840	$\frac{3}{32}$
...	...	...	...	...	...	...	..	..	28 520	$\frac{9}{64}$
...	...	...	...	...	...	...	..	..	34 573	$\frac{5}{32}$
...	...	...	...	...	...	...	..	..	38 598	$\frac{11}{64}$
...	...	...	...	...	...	...	..	..	43 794	$\frac{3}{16}$
...	...	...	...	...	...	...	..	..	48 517	$\frac{7}{32}$
...	...	...	...	...	...	...	..	..	53 745	$\frac{1}{4}$
...	...	...	Pile failed by buckling			...	..	..	59 738	$\frac{9}{32}$
...	...	...	...	...	...	...	..	..	64 977	$\frac{5}{16}$
...	...	...	...	...	...	...	..	..	70 255	$\frac{5}{16}$
...	...	...	...	...	...	...	..	..	74 229	$\frac{11}{32}$
...	...	...	...	...	...	...	..	..	79 209	$\frac{11}{32}$
...	...	...	...	...	...	...	..	..	84 748	$\frac{13}{32}$
...	...	...	...	...	...	...	..	..	86 728	$\frac{3}{16}$

TABLE 7.

TEST OF PILES IN NEW SITE OF MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

Identity.	Character.	Total Length in Ground (Feet).	Length in Sand, Gravel or Clay (in Feet).	Tip Diameter (in Inches).	Weight of Hammer (Lbs.).	Fall of Hammer (in Feet).	Penetration Last Blow (in Inches).	Formula Value.	Test Load (Pounds).	Settlement (Inches).
No. 1	Raymond Concrete	23.2	Sand and gravel 10.2	8	No. 1 Vulcan. Weight of moving parts 5 000 lbs.	2.25	5 blows per inch.	. .	41 050	0
. . . . .	Near No. 14 Wood Pile given by Mr. Worcester.	. . .		. . .		. . .		. .	46 070	$\frac{1}{16}$
. . . . .		. . .	. . . .	. . .		. . .		. .	61 810	$\frac{1}{16}$
. . . . .		. . .	. . . .	. . .		. . .		. .	81 840	$\frac{5}{64}$
. . . . .		. . .	. . . .	. . .		. . .		. .	86 710	$\frac{3}{32}$
. . . . .		. . .	. . . .	. . .		. . .		. .	90 890	$\frac{1}{8}$
. . . . .		. . .	. . . .	. . .		. . .		. .	100 330	$\frac{5}{32}$
. . . . .		. . .	. . . .	. . .		. . .		. .	125 340	[illegible]
. . . . .		. . .	. . . .	. . .		(Pile did not fail)			144 770	$\frac{1}{4}$
. . . . .		. . .	. . . .	. . .		. . .		. .	171 750	$\frac{11}{32}$
. . . . .		. . .	. . . .	. . .		. . .		. .	182 120	$\frac{13}{32}$
No. 2	Raymond Concrete	17.5	Sand and gravel 6.4	8	5 000	2.25	4 blows per inch.	. .	29 650	0
. . . . .	. . . .	. . .		. . .	No. 1 Vulcan	. . .		. .	44 420	$\frac{1}{16}$
. . . . .	. . . .	. . .	. . . .	. . .		. . .		. .	59 360	$\frac{1}{8}$
. . . . .	. . . .	. . .	. . . .	. . .	. . . . .	. . .		. .	110 630	$\frac{3}{16}$
. . . . .	. . . .	. . .	. . . .	. . .	. . . .	. . .		. .	122 280	$\frac{1}{4}$
. . . . .	. . . .	. . .	. . . .	. . .	. . . .	. . .		. .	126 700	$\frac{5}{16}$
. . . . .	. . . .	. . .	. . . .	. . .	. . . .	. . .		. .	131 610	$\frac{3}{8}$
. . . . .	. . . .	. . .	. . . .	. . .	(Pile did not fail)				158 104	$\frac{13}{32}$
. . . . .	. . . .	. . .	. . . .	. . .	. . . .	. . .	. .	. .	160 980	[illegible]
. . . . .	. . . .	. . .	. . . .	. . .	. . . .	. . .	. .	. .	175 870	$\frac{19}{32}$
No. 4	Simplex Concrete	12.4	Sand and gravel 4.0	16	3 300	12	$\frac{1}{4}$	. .	42 490	$\frac{1}{64}$
. . . . .	. . . .	. . .		. . .	. . . .	. . .	. .	. .	61 280	$\frac{1}{8}$
. . . . .	. . . .	. . .	. . . .	. . .	. . . .	. . .	. .	. .	85 800	$\frac{3}{16}$
. . . . .	. . . .	. . .	. . . .	. . .	. . . .	. . .	. .	. .	95 910	$\frac{3}{16}$
. . . . .	. . . .	. . .	. . . .	. . .	. . . .	. . .	. .	. .	133 790	$\frac{3}{16}$
. . . . .	. . . .	. . .	. . . .	. . .	(Pile did not fail)			. .	153 810	$\frac{1}{4}$
. . . . .	. . . .	. . .	. . . .	. . .	. . . .	. . .	. .	. .	177 020	$\frac{9}{32}$
. . . . .	. . . .	. . .	. . . .	. . .	. . . .	. . .	. .	. .	187 270	$\frac{11}{32}$
. . . . .	. . . .	. . .	. . . .	. . .	. . . .	. . .	. .	. .	192 270	$\frac{7}{16}$

carried at $\frac{1}{4}$-in. settlement was divided by $2\frac{1}{2}$, and the result used for the new value of the pile.

Piles enclosed in squares on Fig. 8 were load tested, some of the most important of which are recorded in full in Tables 4, 5, 6 and 7.

After determining that wood piles were to be used, it became necessary to make a sufficient number of tests in order to determine the kind and length to use in different parts of the site.

This task was rather difficult, owing to the great variety of soil conditions found, as will be seen by reference to the geological sections and pile driving reports.

It will be noted that the investigations were first carried on largely on the sites of the buildings forming the westerly part of the group where both spruce and oak test piles were driven.

Referring to Table 1, which is a summary of spruce test piles driven and tested, it will be seen that spruce piles Nos. 1 to 10 inclusive were driven into the "glacial gravel," which at these locations is a well compacted and deep bed of material commonly known as coarse sand and gravel, — to varying depths, and upon being pulled were all found to be broomed or both broomed and broken. Three of these piles, Nos. 3, 5 and 7, were assumed to be good at the time of driving, and were load tested before being pulled.

The results of such tests, because of their crippled condition, which was discovered after the tests were made, were of no special value except to show how these broomed and broken piles acted under load, and the following brief description of these is given for that purpose.

Spruce pile No. 3, about 17 ft. 0 in. long; 9 in. diameter butt and 6 in. tip, driven with 2300-lb. hammer and given short drops until the last few blows, where an average of 9 ft. 8 in. drop was given and a value of 16.7 tons obtained when using the *Engineering News* formula. This pile passed through about 10 ft. 6 in. of loose sand, silt, shells and blue-black mud, and penetrated into coarse sand and gravel about 3 ft. 9 ins.; but when pulled, after load testing, was found broken at about the surface of the gravel and badly broomed at the break.

When tested with a load, this pile, No. 3, carried 5.5 tons

without noticeable settlement; but when this load was doubled, it settled $\frac{1}{4}$ in. As would be expected, the settlements were marked, and under a total load of 48 674 ran from $\frac{19}{32}$ in. to 1 in.

Pile No. 5. Spruce, having an 11 in. butt, 6 in. tip, driven with 2300-lb. hammer and with an average drop of hammer of 6 ft. 2 ins. for the last blows, showed an average settlement of $\frac{5}{8}$ in. per blow, which gives a formula value of 8.77 tons.

This pile passed through about 9 ft. 7 ins. of loose sand, silt, shells, silt and black mud, and penetrated the coarse sand and gravel for about 5 ft. 1 in., but when pulled was found badly broomed and broken just below the top of the gravel.

When tested with a load, this pile carried 6.8 tons with a total settlement of only 1/32 in., but it settled quite rapidly for increasing loads.

Under about 18 tons load, the settlement was $\frac{7}{16}$ in. and showed a marked tendency to get out of plumb. Under about 20 tons the total settlement amounted to over 1 in.

This pile showed great unreliability.

Pile No. 7. Spruce, about 18 ft. 4 ins. long, 10 in. butt by 6 in. tip, driven with 2300-lb. hammer having an average drop at last blows of 10 ft. 0 in., and an average settlement of $1\frac{3}{4}$ in. at last blows, which gives a carrying value of 8.4 tons.

This pile passed through about 9 ft. 2 ins. of loose sand, gravel, shells and mud fill, and penetrated the glacial gravel deposit about 5 ft. 9 ins., and when pulled was found broken and broomed just below top of the gravel.

When tested with a load, this pile settled $\frac{1}{16}$ in. under a load of about three tons, and the rate of settlement was quite rapid under succeeding increments, amounting to over 1 in. under about 15 tons, to over 2 ins. under 26.5 tons, and over 3 ins. under 32.75 tons.

After the load was removed, this pile recovered $\frac{1}{2}$ in. of settlement, showing the effect of the brooming.

It was plainly evident that spruce piles could not be driven, with safety, into the harder portions of this glacial deposit. After a study of the results obtained by a number of spruce piles which had been driven and pulled, it was thought best to limit the use of spruce to those places where friction was largely

depended upon to give the bearing value and very little dependence placed on point bearing.

The test piles also showed that it was easily possible to drive spruce piles, which appeared to be good to the piling foreman and inspector, but which were actually found to be broomed and broken when pulled.

This discouraged the use of spruce piles where sudden changes in the hardness of the soil were found or expected.

Some of the marked and unaccountable settlements of structures which have been recorded in the past may have been due to some extent to the practice of driving spruce piles to or somewhat into hard crusts, thus resulting in brooming of the piles.

Later tests also proved that first-class oak piles could be driven without injury into well-compacted coarse sand or fine gravel to a resistance giving a value of eighteen tons or more.

Oak piles were used where the driving was hard, and where the supporting value of the piles was to be gained largely from point bearing and relatively small embedments in the hard stratum.

For safety a maximum limit of about ten tons was permitted for spruce and fourteen tons for oak.

The *Engineering News* formula was used in determining values of piles for these foundations, and for convenience curves were made up showing safe loads for piles for various weights and drops of hammers.

This formula is as follows:

$$P = \frac{2Wh}{S+1}, \text{ in which}$$

P = Supporting power in pounds.
W = Weight of hammer in pounds.
h = Fall of hammer in feet.
S = Penetration in inches.

Referring to Figs. 2, 3, 4, 5 and 6, it will be seen that a great variety of soil conditions was found.

The glacial deposit ranged from a well compacted gravel and coarse sand, to fine sand, and from 35 ft. in thickness to

nothing, so that in parts of some buildings it was necessary to depend upon the clay for support.

A hard crust was found in only a few locations on either the "glacial gravel" or clay.

The clay in general was found to be of a remarkably uniform grade, designated as "medium," being neither very "stiff" or "soft" except in a few places.

From the driving records and sections it would seem that the surface of the glacial deposit was very uneven in places, as piles which were driven within a few feet of each other would find good bottom at levels differing by 10 to 15 ft. or even more.

These conditions made it difficult to get uniform pile values, and increased the cost of the pile driving.

A fill was often found over the original mud flats, consisting of material such as mud, silt, shells and gravel, which in some places was very compact, offering considerable resistance to the piles, and raising the formula value of all such piles above the true value.

This high but untrue value was corrected to some extent by subtracting the value found while the pile is still in the fill, from the final value.

Not only will the hard fill, above the peat, etc., give the piles driven through it a high formula value at the time of driving, but may afterward add to the actual loads on the piles, by reason of its friction when the peat or mud stratum becomes reduced in thickness, through decay or displacement.

The varying conditions found made it necessary to take particular care to design the pile foundations on the basis of as nearly uniform settlements as possible. This uniformity is highly desirable in order to prevent over-stressing the more or less continuous concrete floor beams and slabs used in the superstructure of the buildings.

The working values have been taken at about $\frac{1}{16}$-in. settlement, as shown by the tests, as it is believed that most piles have an initial settlement, whether noted or not, and considerable care was taken at these tests to note settlements at all times of changes as small as $\frac{1}{64}$ in. It is also believed that the effect of a difference in settlement of $\frac{1}{16}$ in. in the foundations can be safely ignored.

A settlement of $\frac{1}{4}$ in. was considered to be the limit of usefulness of a pile, and it was assumed that greater settlements than $\frac{1}{4}$ in. might create conditions which would cause very unsatisfactory results.

VALUE OF TEST PILES IN CLAY
IN NEW SITE OF MASS. INST. OF TECHNOLOGY

Identity	A Formula Value	B Allowable Value	C Difference	D Curve Value	E Working Value = A+D
2a-2a	7.16	9.0	1.84	1.24	8.4
14a-5	5.5	7.5	2.00	1.40	6.9
12d-6	6.5	12.0	5.50	3.20	9.7
12g-12	5.9	12.0	6.10	3.70	9.6
11a-6	4.5	8.4	3.90	4.30	8.8
10a-18	5.8	8.2	2.40	4.60	10.4
n8-41	8.5	10.8	2.30	4.20	12.7

Values in tons.

Notes:— Values in column "A" are according to Eng. News Formula.
Values in column "B" are derived from tests noted in tables of test piles.
Values in column "C" show differences between "A" and "B".
Values in column "D" show approximate increase over formula values for different penetrations of piles in clay.
Drop hammers used.

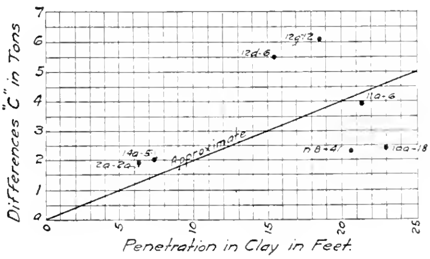


FIG. 9.

It was also considered necessary that the piling have a safety factor of not less than 2.5 of tonnage, based on the limit of $\frac{1}{4}$-in. settlement. From the results of the test piles it is evident that in the majority of cases the piles had to be driven quite deeply into the glacial deposit in order to assure a satisfactory tonnage, but the effort was made to keep the piles in the glacial deposit, even where it thinned up, as it was desirable to use this

stratum as a medium for spreading the loads over the clay under it. An effort was made to have a minimum of at least three feet of "gravel" under the points even where it became thin, in order to make the spreading of the load somewhat effective. It was found, however, that there were places where the gravel was very thin, giving very little value to the piles, and if depended on alone would make the piers over them large and expensive.

When the glacial deposit was found to be thin or disappeared altogether, it then became necessary to depend directly on the clay for support.

The clay, with almost no exception, was without a hard surface or crust, and in order to ascertain its value under working and ultimate loads, some piles, which were driven both partly and wholly into the clay, were load tested.

Two of these were also redriven, as well as a number of others not shown.

Regarding the safe working values, it was found, from the tests, that piles driven into sand and depending upon friction for support, could be used at their formula value, but not much higher, for the limits of settlements and safety factor assumed.

On the other hand, piles embedded in the clay found at this site showed an ability to carry test loads in excess of the formula value when using drop hammers. Referring to the curve shown on Fig. 18, it will be seen that the allowable increase of the formula value appears to be about one ton for every five feet of embedment in the clay. These tests would appear to allow us to believe that, for drop hammers driving wood piles into clay such as found at this site, the *Engineering News* formula could be modified and used as $\frac{3Wh}{S+1}$.

This was taken full advantage of where the gravel and sand became either unreliable, of no practical value, or disappeared, as in a part of Building 17 and others.

Piers were frequently made in clay in which the average formula value of its piles was six tons and less, but owing to the high value shown by tests these were allowed a value fully 50 per cent. greater, provided it was evident that they were well embedded in the clay.

An examination of the reports of piles 12, 6 and 18, in Buildings 6, 4 and 15, respectively, shows a high tonnage at $\frac{1}{16}$-in. settlement; but when compared with the tonnage at $\frac{1}{4}$-in. settlement, a low factor of safety is found; but when reduced to get a factor of about 2.5, it will be seen that there is still a very substantial amount above the formula tonnage, found at time of driving.

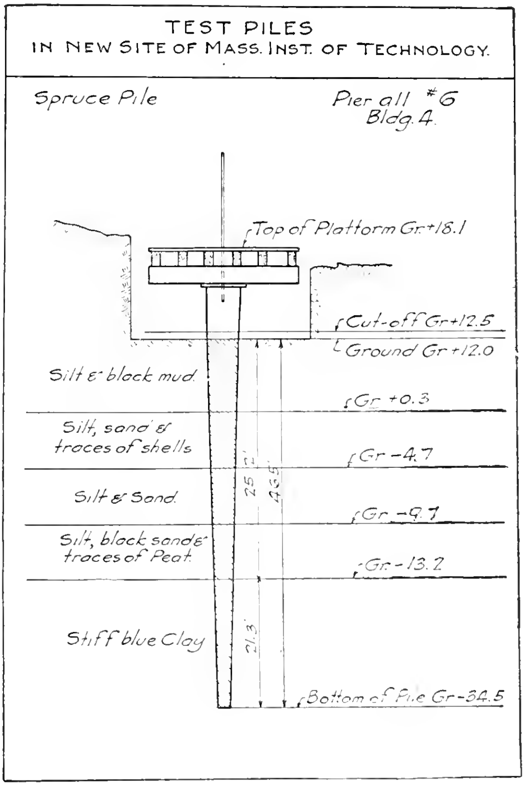


FIG. 10.

It is interesting to see, by the table, that the formula tonnage found by re-driving the piles, after they had been allowed to thoroughly set, did not represent either the value under test load, at $\frac{1}{16}$-in. settlement, or the "allowable" tonnage.

Figs. 10, 11 and 12 illustrate some of the wood test piles and the character of the soil in which they are embedded.

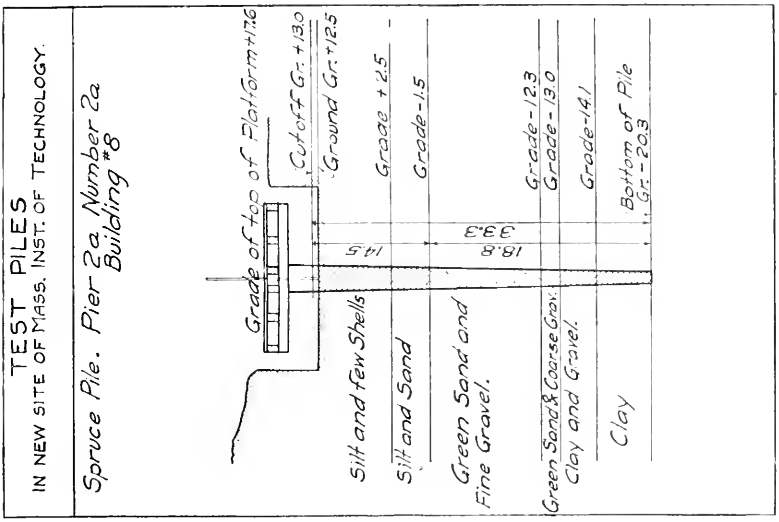

TEST PILES
IN NEW SITE OF MASS. INST. OF TECHNOLOGY.
Spruce Pile. Pier 2a Number 2a
Building #8
Grade of top of Platform +17.6
Cutoff Gr. +13.0
Ground Gr. +12.5
Grade +2.5
Grade -1.5
Grade -12.3
Grade -13.0
Grade -14.1
Bottom of Pile
Gr. -20.3
14.5
18.8
33.3
Silt and few Shells
Silt and Sand
Green Sand and
Fine Gravel.
Green Sand & Coarse Grav.
Clay and Gravel.
Clay

FIG. 12.

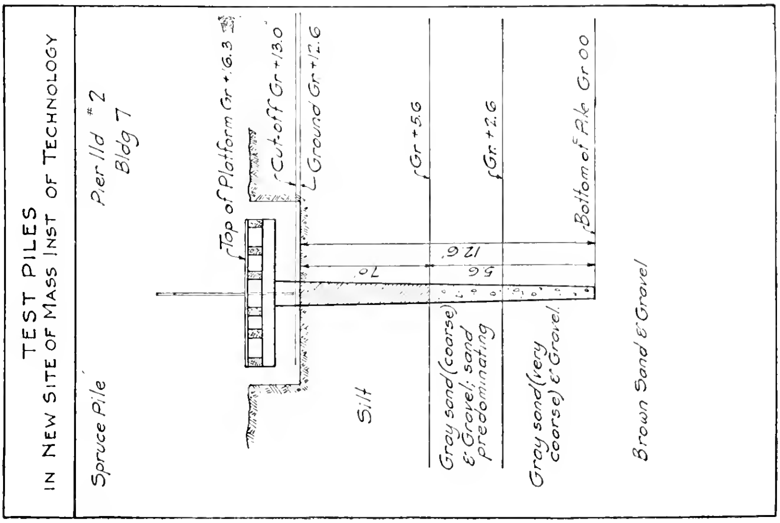

TEST PILES
IN NEW SITE OF MASS INST OF TECHNOLOGY
Spruce Pile
Pier 11d #2
Bldg 7
Top of Platform Gr +16.3
Cut-off Gr +13.0
Ground Gr +12.6
Gr +5.6
Gr +2.6
Bottom of Pile Gr 0.0
7.0
5.6
12.6
Silt
Gray sand (coarse)
& Gravel; sand
predominating
Gray sand (very
coarse) & Gravel.
Brown Sand & Gravel

FIG. 11.

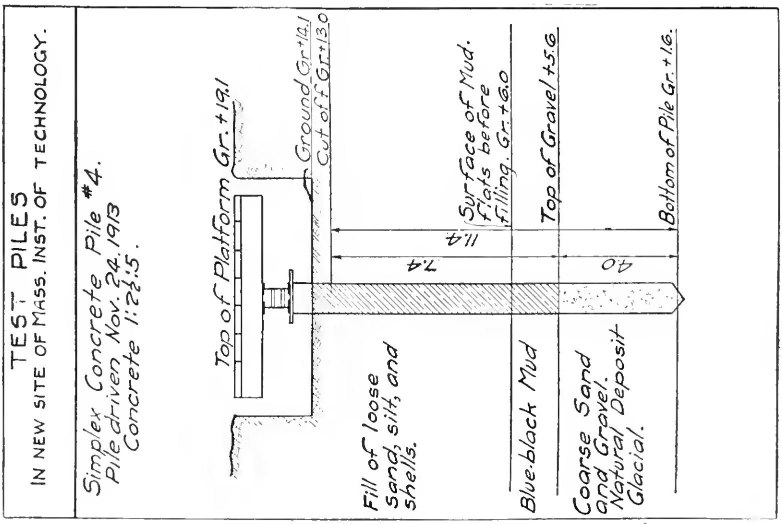

TEST PILES
IN NEW SITE OF MASS. INST. OF TECHNOLOGY.
Simplex Concrete Pile #4.
Pile driven Nov. 24, 1913
Concrete 1:2½:5.
Top of Platform Gr. +19.1
Ground Gr. +14.1
Cut off Gr. +13.0
Surface of Mud-flats before filling. Gr. +6.0
Top of Gravel +5.6
Bottom of Pile Gr. +1.6.
11.4
7.4
4.0
Fill of loose sand, silt, and shells.
Blue-black Mud
Coarse Sand and Gravel. Natural Deposit Glacial.

Fig. 13.

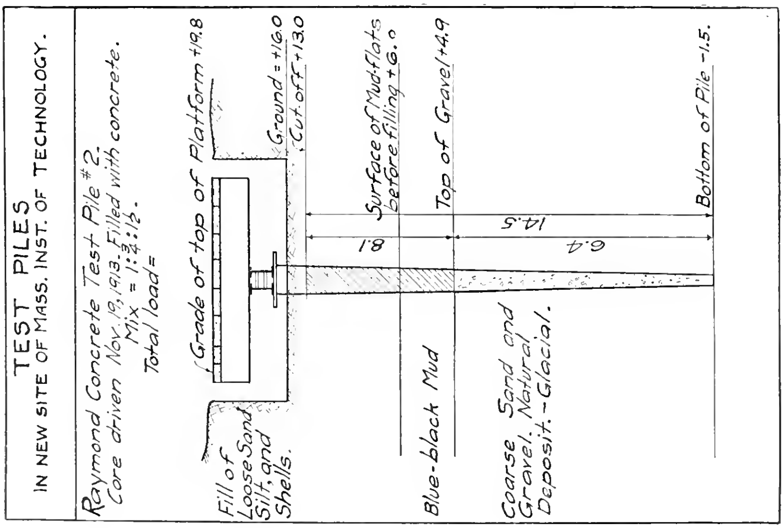

TEST PILES
IN NEW SITE OF MASS. INST. OF TECHNOLOGY.
Raymond Concrete Test Pile #2.
Core driven Nov. 19, 1913. Filled with concrete.
Mix = 1:4:1½.
Total load =
Grade of top of Platform +19.8
Ground = +16.0
Cut off +13.0
Surface of Mud-flats before filling +6.0
Top of Gravel +4.9
Bottom of Pile -1.5.
14.5
1.8
6.4
Fill of Loose Sand Silt, and Shells.
Blue-black Mud
Coarse Sand and Gravel. Natural Deposit. - Glacial.

Fig. 14.

Fig. 13 shows one Simplex pile which was load tested, and the soil in which it rested.

Fig. 14 shows one Raymond pile under similar conditions.

Another feature, in the problem of these foundations, which was given some consideration was the matter of vibration, due to internal and external forces.

Without question it was necessary to construct the foundations in such a way as to reduce the possibility of vibration to a minimum, not only for comfort but because some of the laboratories will contain instruments of special accuracy and delicacy.

Special care has been taken regarding the foundations of heavy testing machinery, to reduce the possibility of settlement and excessive vibration, by placing a sufficient number of well-driven piles under such machines and allowing about 50 per cent. of the value given piles under the building walls.

The greatest vibration will come to the structures from external sources, such as engines in nearby power houses, freight trains, electric cars, etc., conveyed to the buildings by means of the comparatively hard top fill which lies over the stratum of mud, silt and peat.

Peat is found in some locations within the building site, and is probably general on the north and east sides of the buildings, extending through that portion of East Cambridge where a number of factories and power houses are located. Nearly the entire site of the new buildings has a stratum of silt, mud and fill above the glacial deposit and clay. The buildings have therefore a foundation of piles which for their entire lengths, above that part embedded in sand and gravel or clay, pass through a material affording very little lateral support.

Under the action of driving piles, this material often softened up to such an extent as to allow the piles to vibrate strongly, often throwing mud and water out around them.

Structures which are supported on piles passing through such soft, water-filled strata, not only readily send out vibrations but are strongly affected by vibrations from other sources, if situated along the same strata.

One method of partially resisting such a tendency is to

drive the piles well into the supporting stratum, rather than resting them on the surface or with a foot or two of penetration.

As the pile tests show that it was generally necessary to get a fair embedment, in order to get the bearing values desired, it was made unnecessary to largely increase that embedment in order to gain stiffness.

In general, the unit stresses per pile averaged 9.5 tons for interior piers and one-half to three-quarters of a ton less for exterior piers and walls.

It is believed that if settlements occur, the small difference in loading will tend to make slightly greater settlements in the center of the building and prevent the bulging tendency of walls, which would occur if the wall piles settled more than the interior piles.

The working rules for governing the driving of piles are as follows:

1. Spruce piles should not be driven when "hard" driving is found, irrespective of the cause.

2. Driving shall be called "hard" when the penetration per blow of or equivalent of a 2300-lb. hammer at a drop of 10 ft. is less than $1\frac{1}{4}$ in. (which equals 10.2 tons by the *Engineering News* formula).

3. Where greater penetrations are found with equivalent weight of hammer and drop, it shall then be called "easy" driving.

4. When "easy" driving is found, all piles should be driven into the glacial drift 12 ft., provided an average bearing value of 10 tons is obtained in the group.

5. If a 10-ton average cannot be obtained, then longer piles shall be driven to greater depths *in the glacial drift*, in order to get an average of 10 tons. The minimum value for averages should be 8 tons; the maximum, 11 tons, for spruce.

6. If an average value of 10 tons cannot be obtained in any group or pier with a reasonably long pile, say up to 50 ft., then it will be best to stop the driving at such a place, and get a new design for the group, based on values which are indicated.

7. Use oak piles for all "hard" driving and at other places as hereinafter specified.

8. Drive oak piles into the "drift" at least 7 ft., if possible, but do not exceed a value of 14 tons, in attempting to get that penetration.

9. If oak piles do not show a value of 10 tons when driven into "drift" 7 ft., then drive deeper until it is obtained.

10. Do not drive piles through the drift into the clay, as the bearing power must be obtained in the stratum of glacial drift if possible.

11. In those parts of the job where there is any possibility of going through the drift, proceed as follows:

Drive a long, oak test pile in the center of each group of piles supporting each column, with the object of finding the probable depth of the drift.

If the drift is not thick enough to allow spruce or oak piles to be driven in the regular way, then deduct 3 ft. from the thickness of the drift and drive all piles to the new grade, thus keeping all pile points 3 ft. above the clay.

If this results in a low average value for the group, then more piles must be driven to bring the total value of the group up to the required total.

The question whether spruce or oak shall be used in such a case will be determined by the same rules as for any other parts of the work.

If at any time the drift tightens up, so that the penetration per blow is below $1\frac{1}{4}$ ins. when using a drop hammer weighing 2300 lb. at a drop of 10 ft. 0 in. or the equivalent, then use oak.

12. Where a hard fill is found above the glacial drift, it will be necessary to drive oak piles into the glacial drift the usual distance, regardless of the fill.

13. Where the drift is thin or not found, and clay depended upon, piles are to be driven having not less than 18 ft. embedment for medium clay or equivalent, and not more than 9.5 tons shall be allowed them in designing the footings.

Foundations above Piles.

Reinforced concrete spread footings were used to distribute the wall and column loads to the piles. Such footings are per-

missible only when placed on a compressible surface of practically uniform resistance.

This will produce bending stresses in the footings, similar to those produced by a uniformly distributed load.

The permanent ground water level was such as to permit

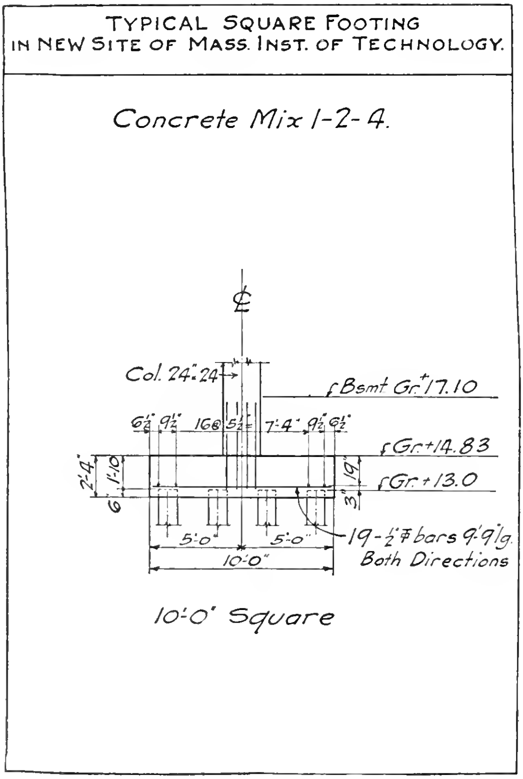


FIG. 15.

the cut-off grade of piles to be fixed at +13.00 Cambridge datum, and is 4.10 ft. below the basement floor level. The permanent water level is not less than +13.00 Cambridge datum.

With few exceptions, the difference of 4.10 ft. between floor and pile cut-off permitted the reinforced spread footings to be placed without lowering the cut-off.

The design of these footings was based on the formulæ recommended by Prof. Arthur N. Talbot, of the University of Illinois, in Bulletin No. 67, the formulæ being determined from the result of many experiments.

The working stresses are those recommended in the report

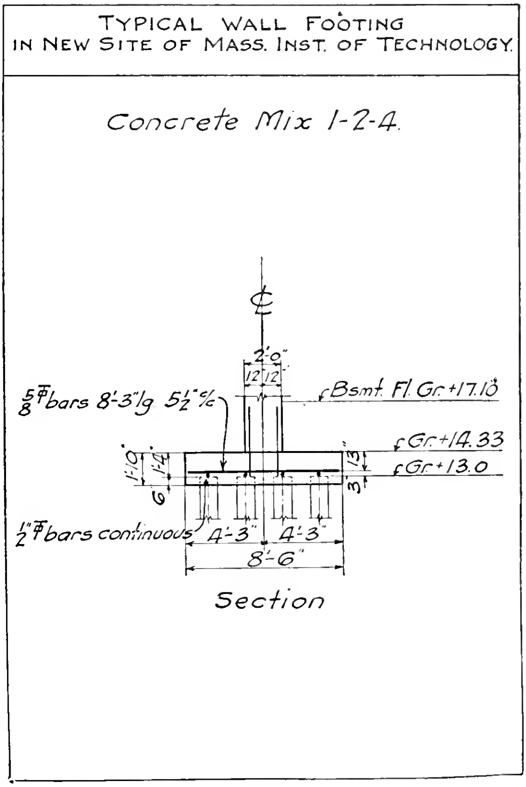


FIG. 16.

of the Joint Committee on Concrete and Reinforced Concrete, except that a maximum of 18 000 lbs. per sq. in. tension was allowed for square rods, cold twisted.

With this general type of footing it is recognized that the piles immediately under the load will be stressed somewhat higher than those at the edges, but this tendency was reduced

to some extent by making the depth of the large footings somewhat greater than strictly required.

This is especially necessary in cases of oblong footings, where the dimensions are 20 ft. by 10 ft., for example, in order that the piles directly under the column shall not be excessively loaded.

The reinforcing steel used in these foundations was mostly square bars, cold twisted.

The pile heads were covered with concrete to a distance of 6 in. below their tops, while the steel was placed with at least 2 in. of clearance above the tops of piles, affording ample protection against rusting or deterioration of any kind.

Figs. 15 and 16 show typical square and wall footings.

Discussion.

Desmond FitzGerald.* — This paper by Mr. Main is most interesting. It is remarkable for the care with which the character of the ground was studied and the effort to meet the conditions in each case. I particularly admire the plan of driving the piles well into the clay to ensure a fair bearing, rather than to stop driving when the surface of the clay was reached.

I am afraid that I cannot add much of value to the discussion. My own experience in the driving of piles in Boston is confined almost entirely to the years 1871 and 1872, when I was engineer of the Boston & Albany Railroad. Many of our walls and abutments, round houses and other buildings, were founded on piles. The heaviest structures that I built at that time were the grain elevators at East Boston and at Berkeley Street, not far from the Providence Railroad crossing. In the case of the latter elevator, we used spruce piles and drove through the marsh to a layer of blue clay about 2½ ft. thick, under which was a softer deposit. The driving of the piles was stopped on the 2½-ft. layer, as the resistance to the hammer seemed to be good at that point. Although the weight of the elevator, when filled with grain, was very great, no settlement was ever noticed in the heavy brick walls nor in the piers under the bins. The

* Consulting Engineer, Brookline, Mass.

foundations of the tower for Trinity Church were put in soon after the period of which I speak, and it would be interesting to find the old plans and to see the weight on each pile. As I remember, the foundation was spread to cover a large area. I think the site was in the deepest mud hole in the Back Bay, and an old channel ran directly under the site of the tower.

Mr. Lewis M. Hastings.* I have been very much interested in Mr. Main's paper. I shall also be interested to know how the results of the observation as to the settlement of these buildings come out. It would be a very great achievement in designing if the settlement should be uniform over this large spread of buildings, requiring such a wide diversity of foundation and such a multiplicity of design, — to meet those conditions. The local conditions there are rather unusual and interesting for an engineer. For instance, the Metropolitan Storage Warehouse near the Boston & Albany Railroad is a very large building and very heavy, four or five stories high, and of heavy brick construction. Under the whole of it, they drove piles to what was supposed to be a solid foundation. The building has been constructed in three portions, — the first portion on Massachusetts Avenue was built more than twenty years ago; the middle portion was built some time after that; and again another addition was made toward the southwest still later. That building has had a progressive settlement ever since the first observation was taken on it. We had a heavy bolt set in the building and intended to use that as a bench mark, about twenty years ago. The building has settled something like 1.295 ft. in that time. It might be expected that the building would be a wreck, but it is perfectly intact, and there is hardly a crack in it. That has been a progressive settlement, — progressive in amount but decreasing in rate, — so it seems to be coming down to a rather hard bottom now. Compare that with the result on the pier or abutment wall of Harvard Bridge. That pier or abutment at the sea wall is founded on the gravel without any piles or attempt to carry it on anything but the gravel. There we have also a bench on the capstone of the abutment,

* City Engineer, City Hall, Cambridge, Mass.

and that has not moved in over twenty years. That is a long way out in the river from the Metropolitan Storage Warehouse. That is a very striking anomaly in conditions, — the inland foundation has gone down continuously, while the one further in the river is practically rigid. We have tested that bench from the shore benches repeatedly, and have never been able yet to detect any essential settlement. Perhaps the explanation may be that it is founded on a very deep gravel bed. The gravel there is unusually heavy and deep, making the overlay on this clay a very heavy one. Further inland the gravel overlay is thinner and is nearer the glacial drift and clay that is underneath, extending to bed rock. As you go further toward the northwest, over to the other side of the Boston & Albany Railroad, we have two quite remarkable structures as far as their present condition is concerned. One is the metropolitan sewer, which passes through Portland Street a distance of about five hundred feet from the Metropolitan Storage Warehouse; and the other is the Cambridge city sewer, which passes along parallel with the metropolitan sewer in Portland Street. The metropolitan sewer is quite deep, going down into the natural sand, — through the filling and peat overlay, and into the natural sand. The city sewer was not so deep, but the foundation was carried down to the same sand with masonry or piling. Now, at the point near the junction of Albany and Portland streets, the maximum settlement was about three and a quarter feet. At "Fort Washington," about three thousand feet southwesterly, the sewer remains practically at grade, and at Broadway near the Mason and Hamlin Organ Company Building, about sixteen hundred feet northeasterly, it is at grade again, — so that between these points the metropolitan sewer is working as an inverted siphon. The city sewer is in the same condition at this point, being now about three feet below the original grade. At the point of greatest settlement above referred to, a boring was made by Past President Charles R. Gow, and it was carried one hundred forty-three feet below the surface to bed rock, and five feet more into the rock. From the level of the metropolitan sewer down to the rock, nothing but sand and clay was found by Mr. Gow. An-

other curious thing is that this settlement extends in a westerly direction away from Charles River and its muddy shores, for more than half a mile, to where the soil, thoroughly tested by borings for the "Cambridge Main Street Subway," consists entirely of sand and the underlying clay. Even here substantial settlements have occurred. Heavy brick buildings founded on the sand have settled from one to two feet without rupture of walls or foundations. The sewer in Main Street, running near the northerly boundary of the Technology property, was found to be from one to two feet below the grade at which it was laid although it was built in the sand below which no mud was found by the borings of the engineers for the construction of the subway above referred to.

From a consideration of these and other similar data, it does not seem that the explanation quoted by Mr. Main in his paper from the report by Professor Crosby, to the effect that the various settlements noticed in the vicinity can be attributed to the presence of layers of mud or similar material in the ground upon which the structures rest, is at all adequate or convincing. It seems that either one of the following theories would more fully explain the conditions as they exist there:

First, that the materials upon which these structures which have shown settlement rest — namely, sand and a thick layer of clay — have had more or less of the water which they contain squeezed out by the unusual pressure applied there, thus allowing a gradual compression of these materials showing itself in the settlements noticed.

Second, that there has been a gradual lateral movement of the clay bed at the points where continuous and heavy pressures are applied, causing a subsidence or settlement at these points and possibly a rise in the surface at other points. A study of the borings taken here shows that the clay, while hard and firm at the bottom near bed rock, is generally quite soft and plastic so as to become mobile at the top, and may thus readily become displaced under unbalanced pressures.

Experience here seems to warrant the conclusion that buildings built upon this area, unless extraordinary means are taken

to prevent it, will be subject to a substantial amount of settlement, and that structures must be designed so that the settlement, when it occurs, shall be uniformly distributed and as little in amount as possible. It must be confessed that the conditions as they exist in this tract are such as to render the accomplishment of these designs one of great difficulty.

All engineers will watch with interest the results of the efforts by the designers of the Technology buildings to accomplish these ends.

Vol. V JANUARY, 1918 No. 1

BOSTON SOCIETY OF CIVIL ENGINEERS
FOUNDED 1848

PAPERS AND DISCUSSIONS

This Society is not responsible for any statement made or opinion expressed in its publications

CONCRETE MATERIALS AND DESIGN OF THE NEW BUILDINGS OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY, CAMBRIDGE, MASS.*

By Sanford E. Thompson,† Member Boston Society of Civil Engineers.

(Presented December 19, 1917.)

The construction of the new buildings of the Massachusetts Institute of Technology represents one of the most comprehensive schemes, for an educational institution, that has been developed in this country. Standing upon an area of 50 acres, the buildings themselves cover an area of $3\frac{1}{2}$ acres, and if placed in a straight line would extend some 2 500 ft. in length. Except the stairways, which are of structural steel, reinforced concrete was used throughout, and about 40 000 cu. yds. of concrete and 3 600 tons of steel reinforcement were required.

The main subject of this paper is the structural features of the work, more especially the engineering studies and investigations that determined them. In connection with a general description of the layout of the work, however, the more interesting construction details are taken up.

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* This paper is taken in part from a paper entitled, "Design and Construction of the Massachusetts Institute of Technology Buildings," by Sanford E. Thompson, which was published by the *American Concrete Institute*, July, 1915.

† Of Thompson & Lichtner, Consulting Engineers, 136 Federal Street, Boston, Mass.

Note. Discussion of this paper is invited, to be received by W. L. Butcher, Editor, 715 Tremont Temple, Boston, before March 10, 1918, for publication in a subsequent issue of the Journal.

Arrangement of Buildings.

The complete plan provides for over thirty buildings, with seventeen of the larger and more important grouped around a central court and so arranged and constructed as to form one continuous building.

Besides these, several academic buildings were constructed,

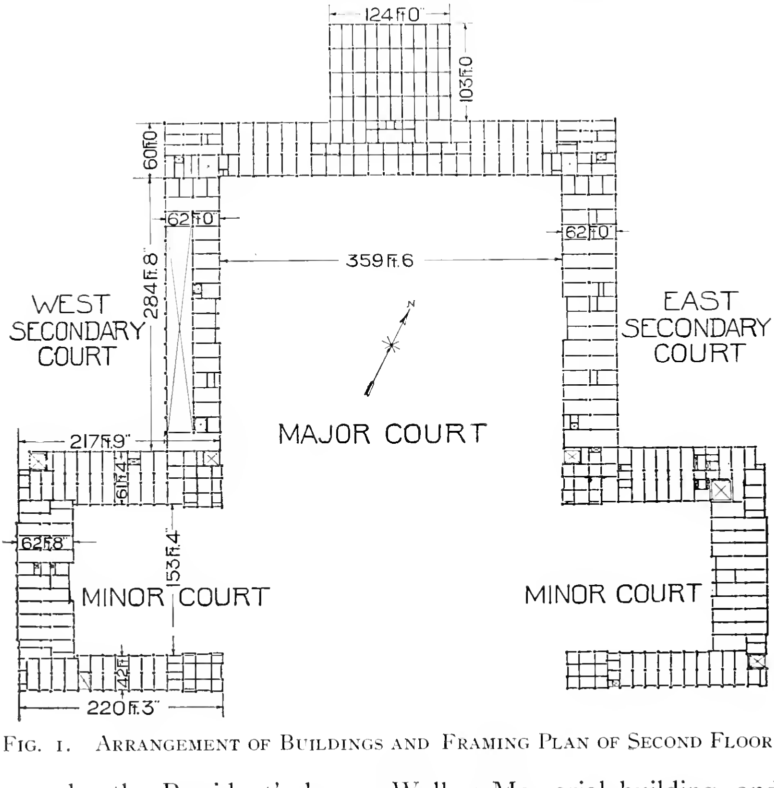


Fig. 1. Arrangement of Buildings and Framing Plan of Second Floor.

namely, the President's house, Walker Memorial building, and dormitories. Although several of these buildings provide interesting features in design, they will not be described in this paper.

The buildings facing directly on the major and minor courts, and on the important streets, are faced with Indiana limestone. On the secondary courts and other less prominent places, pressed brick is used. See Fig. 1.

The buildings on the major court have four stories, and those on the minor courts three, but on these latter are two pavilions that run up to the fourth story, one either side of the main entrance from the street.

The Administration Building, which is in the center of the group, is five stories high and is provided with a dome.

Materials, Tests and Stresses.

Concrete Materials and Tests. — Although eastern Massachusetts is largely covered with glacial deposits of sand and gravel, it is by no means easy to find materials that make first-class concrete. Available sources of supply were sampled and tested before placing the contract for aggregates, and finally a new bank located about twelve miles from the site was opened and the contract made for excavation, screening and delivery.

Immediately after deciding on the aggregate, compression tests of cylinders 8 in. in diameter by 16 in. long were made, to determine the best proportions and allowable stresses. As a result, three mixes were chosen, proportions 1 : 2 : 4, for the footings and foundation walls, 1 : 1½ : 3 for the superstructure, and 1 : 1 : 2 for a few important columns that required especially high stresses.

The cement used was tested regularly at the mill with check tests at laboratory.

As sand tests are fully as important as cement tests, the inspector went to the bank at regular intervals for samples of sand which were sent to the author's laboratory for testing. The specifications required a ratio to standard sand of 70 per cent. for three days and 85 per cent. for seven days. Although this is somewhat lower than the Joint Committee recommendations, it was found that the aggregate produced concrete of the required strength and furthermore the values could be used as absolute minimums on short time tests. As a matter of fact, the tests thus far have averaged 91 per cent. for three days, 100 per cent. for seven days, and 102 per cent. for twenty-eight days, an excellent record, especially for New England sands.

Field Tests. — Two field samples of concrete were taken

regularly on each section of the job at least four times a week for test at fourteen and twenty-eight days, both samples from the same batch in order to arrive at the true relative value. Wherever possible, the samples were taken directly from place; but for beams, columns and girders, this was impossible, and samples were taken from the barrow before placing. The concrete was shoveled into two 14-qt. galvanized-iron pails, carried to the molding yard, remixed to eliminate the segregation of materials due to carrying from the work, and poured into iron molds imbedded in moist sand. The maximum and minimum temperatures were recorded every day. For mass concrete where the aggregate ran up to 2 or 2¼ ins., samples were cast in 8 by 16 in. cylinders, but for the superstructure concrete, where the largest sized aggregate was not over 1½ ins., 6 by 6 by 12 in. prisms were used because the material for the larger size of specimen is too heavy to carry down from the upper stories. The bottom of each mold was formed by a ½-in. iron plate. The concrete was tamped in the mold with a 6-in. ice chopper, taking about the same precautions as were employed on the regular work. Each sample was given one tamp on each face and four tamps at 90 degrees in the center. The time of the operations of dumping into the molds and tamping never exceeded five minutes. Just previous to the initial set, the top surfaces were carefully troweled with a plasterer's trowel in order to obtain uniform bearing for the compression machine. After forty-eight hours the blocks were taken out of the sand, removed from the molds, and reburied in the moist sand where they remained until the day before testing.

Results of Tests. — The average results of these concrete compression tests were as follows:

1 : 2 : 4 concrete, 14 days old, 1 640 lbs.
1 : 2 : 4 concrete, 28 days old, 2 110 lbs.
1 : 1½ : 3 concrete, 14 days old, 2 008 lbs.
1 : 1½ : 3 concrete, 28 days old, 2 520 lbs.

Each value is an average of about 90 specimens, and the per cent. of variation from the mean runs much lower than is usual in construction work because of the care with which the samples were taken and molded.

The increase in strength from 14 to 28 days for the 1 : 2 : 4 concrete has averaged 23 per cent., and for the 1 : 1½ : 3 concrete 25 per cent. The series of laboratory tests conducted last year by the American Concrete Institute Committee on Aggregates showed an increase of 19 per cent. in this period.

The practical value of this system of sampling and testing was shown at the beginning of the job. Some of the specimens of 1 : 2 : 4 concrete gave low test. The method of handling the concrete on the job was changed at once, and subsequent specimens gave proper strengths. To be sure the concrete that had been previously placed was satisfactory, three or four samples were cut out of a solid footing three or four weeks old. After being sawed to a standard 8 by 8 by 16 in. size, they were crushed and the strengths averaged 2 200 lbs., a satisfactory figure for this portion of the structure.

Properties of Reinforcing Steel. — The cold twisted steel used for reinforcement was tested at the mill with the following results:

Yield point varied from 57 000 to 64 000 lbs. and the tensile strength from 70 000 to 81 000 lbs.

Elongation in 8 ins. was 7½ per cent. to 10 per cent., and reduction in area was 33 per cent. for the larger sizes of bars and 15 per cent. elongation with 50 per cent. reduction in area for sizes below ½ in.

The fracture was a half cup.

Bending tests for ½ in. and larger bars were 180 degrees around their own diameters, and, for bars below ½ in., 180 degrees flat.

Phosphorus ranged from .01 per cent. to .02 per cent. and sulphur from .03 per cent. to .04 per cent.

Beam Tests. — The stresses were so chosen that no cracks would be visible under ordinary working loads, and before coming to a decision on these stresses full size T-beams were made and tested.

As a result of the tests it was evident that the cracks in beams reinforced with twisted steel are less objectionable under a steel stress of 18 000 lbs. per sq. in. than cracks in beams reinforced with plain round bars under a stress of only 16 000 lbs. per sq. in. Moreover, so much of the tension was carried by the

concrete that with a theoretical stress of 18 000 lbs. the actual measured stress was only 8 000 lbs. In beams reinforced with twisted steel there were many more cracks than in beams reinforced with plain round bars, but these cracks were all small and well distributed, and therefore unobjectionable, whereas in the plain round bar beams the cracks were larger and more noticeable.

Design.

Complete specifications for the structural design, following substantially the recommendations of the Joint Committee on Concrete and Reinforced Concrete, were drawn up by the author. Only special features are considered in this paper.

Unit Stresses.

The following standard unit stresses are based on the compressive strength of 8 by 16 in. concrete cylinders, tested in the laboratory, using the percentages for different kinds of stress recommended by the Joint Committee on Concrete and Reinforced Concrete.

Item.	1 : 2 : 4 Concrete.	1 : 1½ : 3 Concrete.	1 : 1 : 2 Concrete.
Compressive unit strength of concrete in 8 by 16 in. cylinders	2 000	2 500	3 300
Compressive fiber stress:			
At center of beam	650	810	....
At support	750	930	....
Compressive stress	450	560	750
Shearing unit stress	120	150	....
Bond stress	80	100	....
Ratio of elasticity	15	12	10
Steel tensile stress	18 000	18 000	18 000

Bending Moments. — All beams were considered as continuous. The bending moment coefficients depended upon the arrangement of the columns. In several buildings the continuous beam consisted of two long end spans and one short center span. In this case the ordinary bending moment coefficients were not sufficient and it was necessary to make special

calculations. Fig. 2 shows the typical spans, and Fig. 3 the positions of live and dead load for maximum bending moments for this type of beam. The formulas from which the bending moments are derived are rather complicated and involve integral calculus. Solutions were worked out for the different con-

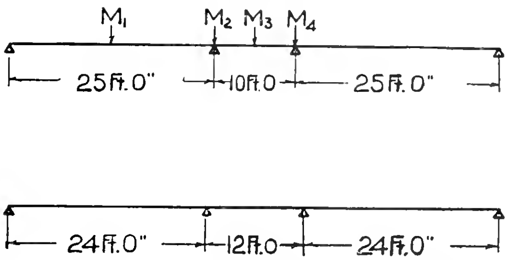


FIG. 2. TYPICAL ARRANGEMENT OF BEAM SPANS.

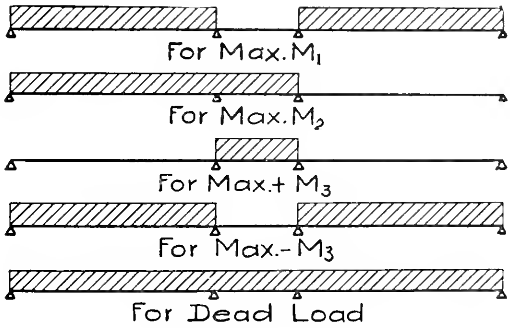


FIG. 3. DIFFERENT POSITIONS OF LIVE LOAD.

ditions, and constants obtained by use of which the general formulas were reduced to the simple ones given below.

Let

M_2 and M_4 = bending moments at center supports.
m_{x1} and m_{x3} = static bending moment at any point in the respective end span due to load in that span.
m_{x2} = static bending moment at any point in the center span due to load in that span.
s = ratio of end span to center span.
l = length of end span.
nl = length of interior span.

Then the general formulas will be as follows:

$$2M_2(l+nl)+M_4nl=-6\left[\frac{1}{l}\int^{l} m_{x_1}xdx+\frac{1}{nl}\int_{0}^{nl} m_{x_2}(nl-x)dx\right]$$

$$M_2nl+2M_4(nl+l)=-6\left[\frac{1}{nl}\int^{nl} m_{x_2}xdx+\frac{1}{l}\int^{l} m_{x_3}(l-x)dx\right]$$

These formulas were solved and constants in terms of dead and live loads derived for different ratios of short span to long span and for different positions of the load.

For design, as a result of these studies, the following simple formulas were used for the three-span continuous beam:

End spans: Center $M_1=\frac{1}{11}wl^2$.

Support $M_2=-\frac{1}{11}wl^2$.

Center spans: Supports $M_2=-\frac{1}{11}wl^2$.

Middle $\begin{cases} M_3=\frac{1}{60}wl^2. \\ M_3=-\frac{1}{18}wl^2. \end{cases}$

In all above cases, l is the length of the end span.

In the several buildings, the arrangement consisted of one center column and two wall columns. In this case the bending moment used at the center and at the supports was $M=\frac{wl^2}{10}$. In computing the bending moment the effect of negative moment at the wall column was considered.

In the administration buildings most of the beams extend over several spans of equal size, therefore ordinary formulas were used. Special treatment, however, was required in the long beams over the lecture rooms, the span of which was 46 ft.

Selection of Spacing of Beams.

The size of the panels, i. e., the arrangement of the columns, was determined by the architectural treatment. To determine

the spacing of the beams in the panel, comparative estimates were made of the relative costs of the following three cases:

Case I. Panel with no intermediate beam; slab 15 ft. 6 ins. solid concrete construction.
Case II. Panel with one intermediate beam; slab 7 ft. 9 ins.
Case III. Panel with no intermediate beam; slab 15 ft. 6 ins. with tile.

The panel with no intermediate beam, slab 15 ft. 6 ins. solid concrete construction, proved the most economical. The interesting result of the estimate was that the cost of forms and not the cost of materials was the determining factor. For instance, in the selected type, the cost of materials was $134 per panel, while in the type with one intermediate beam the cost of materials was only $130. However, the cost of forms in the first case was $36.25 against $48.27 in the second case, so that the total cost of the accepted type was $170.25 against $178.27 of the second type. The cost of the hollow tile construction was more expensive than either of the two concrete types, mainly due to the cost of the tile.

Attention should be called, of course, to the fact that with prevailing high prices of materials, the relative economy of the various types may be different.

In computing cost of forms the book on "Concrete Costs," by Taylor & Thompson, was found very useful.

Administration Building.

The design of the Administration Building presents several features of particular interest. The building is five stories high, and the height from the basement level to the highest point of the dome is around 151 ft.

The building, besides offices and regular class rooms, has two lecture rooms, one on the second floor and one on the fourth floor. The dimensions of the lecture rooms are 72 ft. by 72 ft. The lecture room on the second floor, which is two stories high, is provided with seats amphitheatrically arranged. These rooms have only two interior columns. The girders supporting the floors over the lecture rooms were 48 ft. long, and their di-

mensions 24 ins. by 78 ins. The girders were of special section. The beams supported by these girders were 24 ft. long, spaced 12 ft. on centers.

The fifth floor of the Administration Building, which is used for the library, is of circular shape with a radius of 60 ft. This portion, besides the wall columns arranged in a circle, has eight interior columns which extend to the top of the dome. The wall columns and the wall of the circular portion are supported by a ring girder, which in turn rests on 24-in. by 60-in. girders.

The open space in the library is circular, and is of 72 ft. diameter.

The roof of this circular portion of the Administration Building has the appearance of a dome, the diameter of which is 108 ft.

Originally it was intended to construct the dome of steel ribs; also, a gustovina tile dome of a diameter of 108 ft. was considered. Upon further investigation, however, it was decided to carry the eight interior columns, mentioned before, to the top of the dome, thereby reducing its span from 108 ft. to around 72 ft.

The roof, therefore, is composed of the dome proper of 72 ft. diameter, and a slanting beam and slab construction in which the beams are arranged radially, giving the outside effect of a dome. With this arrangement, it was found possible to construct the entire dome of reinforced concrete.

The slab composing the dome proper was 5 ins. thick on the top, and 8 ins. thick at the haunch. A reinforced concrete ring of suitable dimensions was provided at the haunch, to take the thrust of the dome. This ring rested at the top of the eight columns. The remaining portion of the dome consisted of beam and slab construction, where the beams and slabs were inclined to give the circular effect. The dome slab was reinforced with radial bars and concentric rings.

Beam Reinforcement.

Beams are all continuous, and negative moments were provided for in the design. The location of bends in steel was

always selected so as to leave as much steel as was required for both tension and compression stresses. As a rule, about three eighths of the shear was considered to be carried by the bent

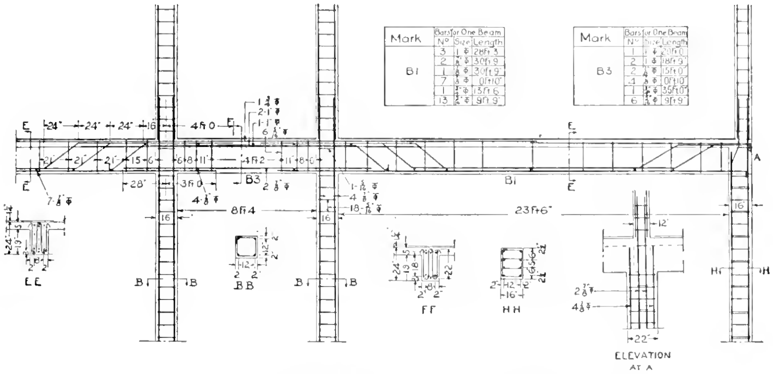


FIG. 4. TYPICAL BEAM AND COLUMN ON MINOR COURT.

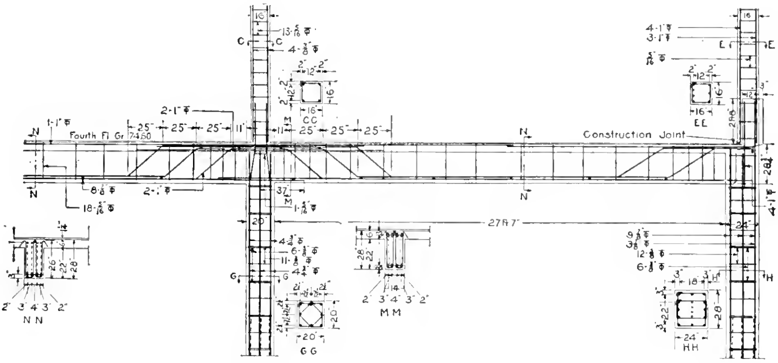


FIG. 5. TYPICAL BEAM AND COLUMN ON MAJOR COURT.

bars in accordance with recent tests. Typical reinforced beams and columns are shown in Fig. 4 and Fig. 5, and typical cross sections of the buildings are shown in Figs. 6 and 7.

Unusually long beams of special design were used in the construction of the pavilions in Buildings 1, 2, 5 and 6, where it was desirable to have class rooms over 40 ft. sq. with no inside columns. Four beams running at right angles to each other,

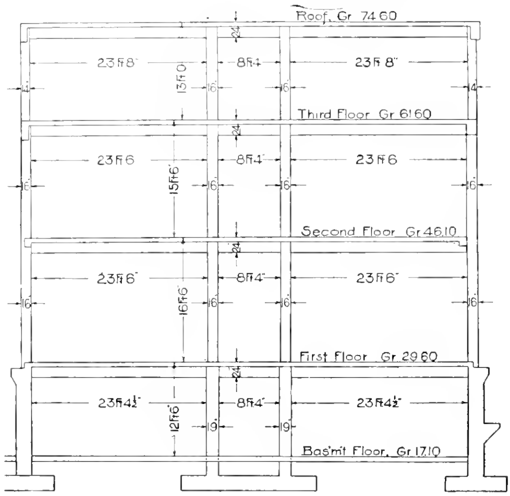


FIG. 6. CROSS SECTION OF BUILDING ON MINOR COURT.

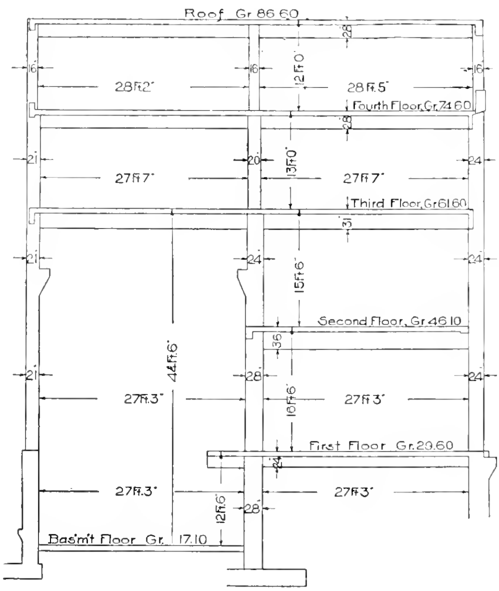


FIG. 7. CROSS SECTION OF BUILDING ON MAJOR COURT.

two in each direction, divided the floor into nine nearly square panels. The beams were 18 by 36 ins., and the reinforcement consisted of six 1-in. and six $\frac{7}{8}$-in. bars at the center and five 1-in. and two $\frac{7}{8}$-in. bars at the ends. All bars were square twisted steel. The pavilion roof beams are also unusually large because of the architectural treatment.

Interior Columns. — All interior columns are square, and reinforced with vertical steel only. Bands were placed 12 ins. on centers to keep the steel in position during construction. The eccentricity of interior columns was neglected because the short beams were designed with sufficient steel to prevent bending in the column.

Wall Columns. — In the design of wall columns account was taken of the bending moment produced by the rigidity of the connection between beam and column. The eccentricity in this case was computed carefully and enough steel provided to take care of it. To provide for the bending moment in the top story, however, it would have been necessary to use larger columns than the architectural treatment would permit. Therefore, to prevent a bending moment in the columns, it was decided to make a joint between the columns and roof beams and not to carry the outside reinforcement through the beam. Columns were then designed for the superimposed load placed on the column with an eccentricity of 0.4 the width of the column.

Slabs. — The floor slabs, which are continuous, were designed for a bending moment $\frac{wl^2}{12}$ at the support and the same moment in the center of the span. To prevent cracks in the building as far as possible, short bars were placed on the top over each girder whenever the main slab reinforcement ran parallel to the girder, and, in fact, wherever there was danger of negative stresses.

Walls. — Retaining walls were cast monolithic with the wall columns except on the outside wall. In the minor and major courts separate retaining walls were built about 3 ft. 9 ins. from the building line.

Floor Surfaces. — Special studies of floors were made and several experimental slabs were built in order to find the method

of placing that would result in minimum dusting and a satisfactory bond with the slab. The scum which always rises on the surface of base concrete was removed by brushing the slab with a wire brush just as it begins to harden. The tests showed that dusting is best prevented by using, with granolithic, coarse sand containing scarcely any dust and mixed with broken stone ranging from $\frac{1}{4}$ in. to $\frac{1}{2}$ in. in size and mixed in a stiff mortar in the proportions $1 : \frac{3}{4} : 1\frac{1}{4}$. As a result of laboratory tests, stiff neat cement brushed into the set concrete was selected as the best bonding material between the base concrete and granolithic.

Vol. V FEBRUARY, 1918 No. 2

BOSTON SOCIETY OF CIVIL ENGINEERS
FOUNDED 1848

PROCEEDINGS

NOTICE OF REGULAR MEETING.

A REGULAR meeting of the Boston Society of Civil Engineers will be held on

WEDNESDAY, FEBRUARY 20, 1918,

at 7.45 o'clock P.M., in CHIPMAN HALL, TREMONT TEMPLE, BOSTON.

Mr. Thomas C. Atwood will give an address on "The Submarine Menace and the Squantum Destroyer Plant." The address will be illustrated with lantern slides.

S. E. TINKHAM, *Secretary.*

NOTICE OF SPECIAL MEETING.

A special meeting of the Society will be held in the Society Rooms, 715 Tremont Temple, Boston, on Wednesday, February 27, at 7.30 o'clock P.M. Mr. Clayton W. Mayers, of the Aberthaw Construction Company, will read a paper entitled, "Economy in the Design of Concrete Buildings."

S. E. TINKHAM, *Secretary.*

SANITARY SECTION.

NOTICE OF ANNUAL MEETING.

THE annual meeting of the Sanitary Section will be held in the SOCIETY LIBRARY, TREMONT TEMPLE,

WEDNESDAY EVENING, MARCH 6, 1918.

Mr. Charles H. Parker, Superintendent Generating Department, Edison Electric Illuminating Company, of Boston, will read a paper entitled, "Economy in the Use of Fuel in Power Stations."

PAPERS IN THIS NUMBER.

"Economy in the Design of Concrete Buildings." C. W. Mayers.

"Sewer Pipe Joints." Topical discussion.

CURRENT DISCUSSIONS.

Paper.	Author.	Published.	Discussion Closes.
"Foundations of the New Buildings of the Massachusetts Institute of Technology."	C. T. Main and H. E. Sawtell.	Jan.	Mar. 10
"Concrete Materials and Design of the New Buildings of the Massachusetts Institute of Technology."	S. E. Thompson.	Jan.	Mar. 10

Contributors are hereby notified that proof will not be submitted to them for examination unless requested before the 10th of the month preceding the month of publication.

MINUTES OF MEETINGS.

BOSTON, January 23, 1918.—A regular meeting of the Boston Society of Civil Engineers was held this evening at Chipman Hall, Tremont Temple, and was called to order by the President, George C. Whipple, at 8 o'clock.

There were 40 members and visitors present.

The records of the last regular meeting and the special meeting of January 11, 1918, were read and approved.

The Secretary reported for the Board of Government the election of the following to membership: In the grade of member, Messrs. Clarance Lester Foster and Pusey Jones, and in the grade of junior Mr. Laurence Arnold Gillett.

The President presented, for the Board of Government, its recommendation that the following vote be passed: *Voted*, that a sum not exceeding one hundred and twenty-five dollars be transferred from the income of the Permanent Fund to the Current Fund, to cover the amount of unpaid dues for the present year of members who are in the war service of the country, and which have been remitted by the Board of Government under authority of the by-laws.

On motion of Mr. White, the recommendation was adopted by a unanimous vote.

The Secretary read a memoir of Otis F. Clapp, late a member of the Society, prepared by a committee consisting of William D. Bullock and Irving S. Wood. The memoir was accepted and ordered printed in the JOURNAL.

The President announced the death of Chauncey D. Bryant, a junior member of the Society, and of the 101st Engineers, which occurred in France on January 5, 1918. The President called attention to the fact that Mr. Bryant was the first member of the Society who had died in the present war service. By vote the President was requested to appoint a committee to prepare a memoir. He has named, as that committee, Mr. Robert Spurr Weston.

On motion of Mr. Eddy, the President was requested to appoint a committee of three to submit to the meeting the names of five members to serve as the committee to Nominate Officers for the Ensuing Year. The President appointed Harrison P. Eddy, Hartley L. White and Frank L. Fuller. Later in the meeting this committee presented the names of Frank A. Barbour, Robert Spurr Weston, George H. Brazer, David A. Ambrose and Dana M. Wood, and by vote they were duly elected as the Nominating Committee.

The paper of the evening was by Mr. Frank B. Walker, entitled, "Engineering Features in Connection with Loading and Hauling Iron Ore from Mesabi Range to Lake Docks." The paper was illustrated with lantern slides, and a number of specimens of the ore were exhibited.

Past President Eddy presided during the latter portion of the meeting, President Whipple having been obliged to leave on account of another engagement.

At 9.45 the meeting adjourned.

S. E. TINKHAM, *Secretary.*

BOSTON, January 2, 1918.—A meeting of the Sanitary Section of the Boston Society of Civil Engineers was held this evening in the Society Library, Tremont Temple. The meeting was called to order at eight o'clock by the chairman, Mr. Frank A. Marston. The minutes of the December meeting were read and approved.

The subject discussed was sewer pipe joints, and the first speaker, Mr. J. Leslie Woodfall, read a very interesting paper relating his experience with various materials in different parts of New England. Mr. E. H. Rogers, city engineer of Newton, gave a detailed account of the method used in that city. Mr. H. A. Varney, town engineer of Brookline, described the various methods which had been used in that town. Mr. Hastings, city engineer of Cambridge, showed a method invented by him, of pouring a cement grout joint. He also described the method used in that city for constructing sewers and drains in wet ground, and showed a diagram of a concrete drain and the method of construction. Mr. Brewer, city engineer of Waltham, related his experience in sulphur and sand joints and several other materials. Mr. Carpenter and Mr. Branch also spoke on the subject. Mr. Neuff, of Adams, described a new method of pipe jointing in which metal gaskets were used instead of the ordinary rope yard.

Eighteen members and visitors were present.

The meeting adjourned at 10.15.

HENRY A. VARNEY, *Acting Clerk.*

BINDING SOCIETY JOURNAL.

The Secretary has made arrangements for binding Volume 4 of the JOURNAL of the Society. The ten numbers will be bound in one volume, the style of binding to be uniform with that of previous volumes. The price of binding this year will be 90 cents per volume.

Numbers for binding must be sent to 715 Tremont Temple, Boston, before March 1, 1918. After this date, numbers will not be accepted for binding except with the understanding that they cannot be bound at the price named.

APPLICATIONS FOR MEMBERSHIP.

[February 12, 1918.]

THE By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission, and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of twenty (20) days from the date given.

KERSTEIN, BENJAMIN HOFFMAN, Dorchester, Mass. (Age 24, b. Boston, Mass.) Graduate of Mass. Inst. of Technology, 1916, civil engineering course, degree of S.B. From 1916 to date, resident engineer with Mass. Highway Com. Refers to A. B. Appleton, Alexander Bresth, R. W. Coburn, H. J. Hughes, J. H. O'Connor, and W. N. Wade.

Moore, Rufus Read, Boston, Mass. (Age 32, b. Milton, Ind.) Graduate of Boston three years' evening course in practical electricity, 1909, and of Northeastern College evening course in electrical engineering, 1916. From October, 1906, to June, 1909, with Lundin Electric and Machine Co., Boston, on repairs and construction work in central and sub-stations; from June to November, 1909, journeyman electrician with M. B. Foster Electric Co.; from November, 1909, to December, 1913, in other than engineering work; from December, 1913, to June, 1914, in charge of all electrical work for Phillips Electric Light & Power Co., Phillips, Me.; from September, 1914, to March, 1915, with various contractors in Portland, Me.; from March to September, 1915, engaged in electrical work on coast defenses of Portland, Me., and New London, Conn., districts; from September, 1915, to August, 1916, with Lundin Electric and Machine Co.; from August, 1916, to November, 1917, chief electrician of maintenance with Gray & Davis, Inc., Cambridge; is now draftsman with Harry M. Hope Engrg. Co., Boston. Refers to W. W. Clifford and C. M. Durgin.

Wansker, Harry A., Boston, Mass. (Age 24, b. New York, N. Y.) Student at Mass. Inst. of Technology, 1913 to 1915; graduate of Rhode Island State College, 1917, civil engineering course, degree of B.S. During summers of 1913, 1914, 1915 and 1916, and from May to November, 1917, with Darrow Mann Co., Charlestown, Mass., and Providence, R. I., on mechanical drafting, surveying, power plant construction and designing electrical apparatus for their large coal-handling plant; from November, 1917, to date, ship draftsman with Hull Division, Boston Navy Yard. Refers to F. A. Caldwell, T. G. Hazard, Jr., Willard Kent and L. E. Moore.

LIST OF MEMBERS.

ADDITIONS.

Allen, Elmer F. ....7 Highland Ave., Stoneham, Mass.
Bunker, Page S.,
Capt., Ordnance Dept., U. S. R., Augusta Arsenal, Augusta, Ga.
Foster, Clarance L. ....32 Central Rd. Somerville, Mass.
Gillett, Laurence A. ....92 Bromfield St., Newburyport, Mass.
Ullian, Hyman B. ....35 Creston St., Dorchester, Mass.
Wells, Edward P.,
Cadet, U. S. A. School of Military Aeronautics, Ithaca, N. Y.

CHANGES OF ADDRESS.

Adams, Edward P. ....1102 Exchange Bldg., Boston, Mass.
Appleton, Arthur B. ....11 Sherman St., Beverly, Mass.
Beard, Cornelius,
1st. Lieut., A Co., 101st Reg., U.S. Engrs., American Expeditionary Force, France
Brown, Albert F. ...36 Maxwell St., Dorchester Center Sta., Boston, Mass.

CRAIB, CHARLES G. 375 Querbes Ave., Outremont, P. Q.
CRAIGUE, JOSEPH S., Capt., D. G. T., American Expeditionary Force, France
DOLLIVER, HENRY F. . . . . 41 Salcombe St., Dorchester, Mass.
GREEN, HOWARD W. . . . . Box 364, Ancon, C. Z.
HARTY, JOHN J., Jr., care Monks & Johnson, 78 Devonshire St., Boston, Mass.
HOBSON, GEORGE F. . . . . . . Capt., U. S. R., 305th Engrs., Camp Lee, Virginia
JOHNSON, FRANK W.,
Raymond Concrete Pile Co., 2006 Finance Bldg., Philadelphia, Pa.
LUTHER, HOWARD B.,
Lieut. (Jun. Grade), U. S. N. R. F., 1707 H St., N. W., Washington, D. C.
PIERCE, CHARLES H. . . . . 1st Lieut., E. R. O. T. C., Camp Lee, Virginia
PRATT, R. WINTHROP . . . . 2847 Broxton Rd., Cleveland, Ohio
REED, LESLIE P.,
2d Lieut., U. S. Signal Reserve Corps, Engrg. Section,
Room 356, Union Sta., Washington, D. C.
WADE, CLIFFORD L.,
1st Lieut., Engrs., U. S. A., care U. S. Geological Survey, Washington, D. C.
WEBB, GEORGE F. P. O. Box 861, Bellows Falls, Vt.
WOOD, CARL W. . . . . 39 Greenleaf St., Malden, Mass.
WOOD, FREDERIC J.,
Major, Engineers, U. S. R., Curtis Bay Ordnance Depot, So. Baltimore, Md.
WORCESTER, ROBERT J. H.,
1st Lieut., Inf. R. C., 12th Co., 3d Battalion, Depot Brigade,
Camp Devens, Mass.
YOUNG, ERVING M.,
care Constructing Quartermaster, Curtis Bay Ordnance Dept., Md.

DEATH.

BRYANT, CHAUNCEY DAVIS, 101st Engineers, American Expeditionary Force.
Died in France, January 5, 1918.

EMPLOYMENT BUREAU.

THE Board of Government maintains an employment bureau for the Society, to be a medium for securing positions for its members and applicants for membership, and also for furnishing employees to members and others desiring men capable of filling responsible positions.

At the Society room two lists are kept on file, one of *positions available* and the other of *men available*, giving in each case detailed information in relation thereto.

Men Available.

417. Graduate of University of Maine, civil engineering course. Has had several years' experience in responsible charge of general building construction, as superintendent and engineer. Is above draft age, and American citizen. Will give Boston interview and references to persons interested.

LIBRARY NOTES.

Recent Additions to the Library.

U. S. Government Reports.

Annual Report of Chief of Weather Bureau for 1916–17.

Annual Report of Superintendent, United States Coast and Geodetic Survey, for 1916–17.

Potash in 1916. Hoyt S. Gale.

Pottery in 1916. Jefferson Middleton.

Salt, Bromine and Calcium Chloride in 1916. Ralph W. Stone.

Spirit Leveling in Mississippi, 1901 to 1915, inclusive. R. B. Marshall.

Spirit Leveling in South Dakota, 1896 to 1915, inclusive. R. B. Marshall.

Strontium in 1916. James M. Hill.

Thorium Minerals in 1916. Waldemar T. Schaller.

United States Magnetic Tables and Magnetic Charts for 1915. Daniel L. Hazard.

State Reports.

New Jersey. Quaternary Formations of Southern New Jersey. Rollin D. Salisbury and George N. Knapp.

New York. Annual Reports of Conservation Commission, Division of Inland Waters, for years 1911 to 1914.

New York. Annual Report of State Department of Health for 1915.

Municipal Reports.

Boston, Mass. Annual Report of Public Works Department for 1916.

Detroit, Mich. Annual Report of Department of Parks and Boulevards for 1916–17.

New York, N. Y. Report of Board of Water Supply on Completion of First Stage of Catskill Water Supply System, 1917.

Philadelphia, Pa. Annual Report of Bureau of Surveys for 1916.

Miscellaneous.

Canada, Department of Mines. Radioactivity of Some Canadian Mineral Springs. John Satterly and R. T. Elworthy.

Contribution of Society of Portuguese Civil Engineers to World's Columbian Exposition, 1893. Gift of Massachusetts Institute of Technology Library.

Hydrated Lime Bureau. Watertight Concrete.

Institution of Civil Engineers (London). Minutes of Proceedings, Vol. CCIII, 1916–17.

Street Railway Fares. Dugald C. Jackson and David J. McGrath. Gift of Massachusetts Institute of Technology.

Sydney University Engineers: Their School and Their Work. James Vicars.

The War, Australia and the Engineer. S. H. E. Barraclough.

LIBRARY COMMITTEE.

NEW ENGINEERING WORK.

(Under this head a brief description of new engineering work contemplated or under construction will be presented each month. Engineers and contractors are requested to send descriptions of their work to the Secretary, 715 Tremont Temple, Boston, before 1st of each month.)

Commonwealth of Massachusetts.— METROPOLITAN WATER AND SEWERAGE BOARD. — *Water Works.* — All of the poles and towers for the transmission line between the Wachusett and Sudbury power stations have been erected, and some of the cross arms have been placed.

At the Arlington pumping station the new three-million-gallon centrifugal pumping unit has been received, and is now being erected.

Metropolitan Water and Sewerage Board. — *Sewerage Works.* — Work in progress: Section 98, Wellesley Extension.

Metropolitan Park Commission. — *Old Colony Parkway.* — Construction of a temporary bridge across the Neponset River between Boston and Quincy is in progress; also construction of double siphon for water and gas under new channel.

Boston Transit Commission. — *Dorchester Tunnel.*— Work is progressing on the interior finish of the station at Andrew Sq., and work is in progress on the station for transfer of passengers from the surface cars to the tunnel below.

New York, New Haven & Hartford R. R. Co.—*South Boston Cut Improvement.* — Enlargement of South Boston Cut to Boston Freight Terminal, to accommodate four tracks instead of two, and reconstruction of eleven overhead highway bridges, so as to span four tracks instead of two, progressing. Excavation by steam shovel has advanced from westerly end of cut through West Fourth St. Bridge abutments being constructed at West Sixth St. and West Fifth St.

Vol. V FEBRUARY, 1918 No. 2

BOSTON SOCIETY OF CIVIL ENGINEERS
FOUNDED 1848

PAPERS AND DISCUSSIONS

This Society is not responsible for any statement made or opinion expressed in its publications

ECONOMY IN THE DESIGN OF CONCRETE BUILDINGS.

By Clayton W. Mayers.*

(To be presented February 27, 1918.).

Part I.

Hidden Wastes.

Upon the designing engineer of concrete buildings rests the big responsibility of conservation of building materials. The mere fact that concrete is composed of cement, sand and stone, of which there seems to be an excellent supply, does not in any way relieve the designer of concrete construction of the obligation of careful study of the work in hand in order that no excess of material be used. Most errors made in concrete design are not easily recognized even by experienced estimators of building construction. Hidden away inside a column there may be reinforcing steel which should be elsewhere doing work at less expense to the owner, as would have been the case had the designing engineer given proper thought to the design of this column. A large percentage of the floor space occupied by columns might be storage space for the same reason. The beams may contain an excess of steel reinforcement simply

* With the Aberthaw Construction Company, 27 School Street, Boston, Mass.

Note. This paper is published in advance of its presentation before the Society. Discussion is invited, to be received by the editor before April 10, 1918, for publication in a subsequent number of the Journal.

because it was less trouble to call for straight top rods to take care of negative bending than it was to determine where and how bends could have been made in order to have used the least amount of reinforcement in the design. Flat slabs may have a number of individual rods over the top of each column head, where a few more bottom rods should have been bent up to take care of this negative bending. And yet this entire building may have been designed in accordance with the recognized standards of concrete design. These errors are not errors in computations, but are errors of careless design, and the result is dire waste of material.

Study for Economy a Necessity.

In most cities, building plans are OK'd by responsible engineers authorized by the city to pass upon these plans before the work is allowed to proceed. Errors in computation are usually detected in this process, but who ever heard of one of these authorized engineers returning a set of plans with suggestions for a more economical design? Provided the building is strong enough, the design is approved. It is not the function of city building departments or their engineers to look for economies or suggest savings.

Hence, if the designing engineer does not study economy in the design of his work, he may be reasonably sure it will get very little such study from any one. Designs prepared without this special study are sure to show a waste of building material, and the building is no better, and serves no better purpose, because of this extra expense.

Recognized standards are observed by most designers of concrete buildings as regards stresses and strains, factors of safety, etc., but unfortunately no rules, tables, or data are at hand which will solve the problem of maximum economy in the choice of the various methods of concrete construction which may be used. Each building presents new problems. It is a case of careful study in an intelligent way, and the designer must do this work well if he would " do his bit " and at the same time keep or build up his reputation.

Is there any position more humiliating to the designing

engineer of a contemplated structure than to have other parties submit to the prospective owners a more economical design based on the same fiber stresses as were used in the original layout? This is not an uncommon event, and uncomfortable complications always arise.

A general survey of conditions and inspection of the possible methods of construction usually constitute the first thought given to a new problem of structural design. By this inspection a process of elimination is set up, and finally the engineer considers only a few schemes which could be well employed to give the owner a structure suitable for his purposes. The next step usually consists of viewing the several schemes from every angle in order to study their individual merits. Each layout possesses different advantages, some of more value than others, but each one would answer the purpose very well. For instance, a beam and girder type of floor construction may offer advantages in the way of hanging shafting if the building is to be used for certain types of manufacturing. Column spacing would perhaps work out to better advantage in one scheme than in another. Thus the discussion continues, with here and there a remark about the probable cost of this and that. A decision is usually made in favor of the scheme offering the most advantages even though they are trivial. The plans are drawn up on this basis, and the work proceeds. The detailed design is finished with about the same attention to costs as has been given to the selection of the type of construction used. Generally, the owner of the completed building is satisfied, and, if he could have had just as good a building for less money, he never knows it.

Comparative Cost Estimating.

The average concrete designer makes no claim to being an estimator. In fact, he does not think it is necessary to be an estimator even of the materials with which he works. It is a fact that a large majority of men employed in the design of concrete buildings have hardly any idea of the cost of the work they are laying out, and what is more, they do not know how to find this out for themselves. Surely, if an engineer designed a structural steel girder he could tell with reasonable accuracy

what it would cost by computing the weight and getting the market price of the structural steel and the labor cost of erection. Estimating the cost of concrete work is a little more complex, but each step is very similar and the process is the same.

A designer of concrete structures should think continually of costs. In order to think intelligently of the cost of his work he must know how to calculate approximately the cost of his designs. In no other way is he able to determine which one of his studies will serve his purpose at the least expense.

It should be borne in mind that in making designs for comparative costs, it is not necessary to work to as great a degree of accuracy as for the finished plans. Rough designs, accompanied by rough sketches, will furnish enough information for this study. In case the comparative costs of two schemes should work out the same, a more careful design might become necessary. A little practice on the part of the designer will soon reveal to him to what degree of accuracy he must work in order to get satisfactory results.

Accuracy of Unit Costs.

The process of estimating these various designs for comparative cost purposes is not nearly as difficult as may be supposed. Concrete is measured by the cubic foot or cubic yard, forms by the surface measurement in square feet, and reinforcement by the pound or ton. After the quantities have been calculated for the various designs, unit prices are fixed and the total cost of the member estimated. It is usually here that the engineer throws up his hands. In fact, it is very likely that he knows but little about the prices of this class of material and labor, and in his rush of work he has not kept in touch with their fluctuations, and feels he does not have time to inform himself properly on this subject. Again, it should be understood that it is not necessary to fix absolutely accurate unit costs to these quantities in order to obtain reasonably accurate cost comparisons. As long as the same unit costs are used for similar types of work in the various designs, the comparative costs will be surprisingly accurate. In fact, some of the unit costs may be in error 25 per cent. or 30 per cent., and yet the resulting costs will show un-

questionably which type of construction should be used. However, the alert engineer will soon become as interested in having his unit costs in accordance with current prices of material and labor as he is in having his design correct.

Effects of Design on Costs.

Contrary to the opinion of most engineers, the concrete building design calling for the least amount of material is not always the cheapest building to erect, as such a building may call for much more labor. Form work is a big factor in the cost of concrete buildings, and this phase of the operation must be given careful consideration in order to simplify the construction of the form work as much as possible. Study must be made also to determine whether the complexity of forms in a comparatively light design would not make the final cost of the building in excess of a building designed of simpler yet heavier construction. Concrete floors designed on the flat slab method sometimes have considerably more material in them and yet work out cheaper than a beam and girder type designed for the same conditions. Placing reinforcement costs more per ton and forms more per square foot in a beam and girder construction than the same operations in a flat slab construction. In laying out floors of the beam and girder type, the addition or omission of one beam per bay may influence the cost of the design a great deal. Changes in column spacings will also have the same effect. It is only by making the design of a typical floor bay of the various schemes considered and getting the quantities and costs of these schemes that it will be possible to tell definitely which method should be used. Many times concrete columns should be composed of a richer mix of concrete and have less reinforcement. In a building of several stories it is necessary to devote considerable study to the design of columns in order to locate the point where the mixes should change, where spirally reinforced columns should be introduced, and also to consider carefully the loss or gain of floor space occupied by columns. It will be necessary to make several sketch designs and calculate the cost of each. Thousands of dollars may be wasted by improper column design and still the error is one which would not readily attract atten-

tion. There is a certain type of design for every part of the construction which will show maximum economy, and it is up to the designing engineer to calculate the costs of his various designs and determine for himself which one should be used.

Unit Costs for Comparative Estimates.

Up to this point this article has emphasized, principally, the necessity of making several preliminary designs of the various members of a concrete building and calculating the cost of each design before the final layout is begun. Not much light has been shed upon the method of obtaining unit prices to fix to the quantities of material and labor. Unit prices are subject to wide fluctuations. Markets, labor, location of the work in question, speed of the operations, etc., and many other items enter into the making of these costs. However, as stated before, these unit prices need not of necessity be extremely accurate, and the designing engineer need not feel that he cannot price closely enough to obtain fairly accurate results.

A list of approximate unit prices have been tabulated here which may be used to calculate the comparative costs of the principal members in a concrete building. Judicious use of these unit costs will enable the designer to incorporate in his design the most economical methods and at the same time develop a keener eye for economical construction.

Concrete.

Concrete (1 : 2 : 4 mix), per cu. yd.	Cement, $1\frac{2}{3}$ bbls. at \$2 per bbl. at the job			\$3.33
	Sand, $\frac{1}{2}$ cu. yd. at \$1.50 per cu. yd. at the job			.75
	Crushed stone, $1\frac{3}{10}$ tons at \$2 per ton at the job			2.60
	Plant, cost per cu. yd.	Freight charges	\$0.05	
		Rental of mixer, etc.	.35	
		Purchases (small tools, fuel and supplies)	.45	
		Labor	.40	
				1.25
	Labor of mixing and placing			1.25
Total cost per cu. yd.				\$9.18
Total cost per cu. ft.				.34

Concrete mixed in the proportion of 1 : $1\frac{1}{2}$: 3 will require about one third of a barrel more cement per cubic yard. This will add about 67 cents to the cost of one yard of concrete in place, making the unit price about \$9.85 per cubic yard, or $36\frac{1}{2}$ cents per cubic foot. If a 1 : 1 : 2 mix of concrete is used, the cement will be increased about $1\frac{2}{10}$ bbl. over and above that used in a 1 : 2 : 4 mix. At \$2 per bbl. this would make the cost of 1 : 1 : 2 mix concrete about \$11.58 per cu. yd., or 43 cents per cu. ft. In large, plain concrete footings it is sometimes advisable to use a concrete mixed in the proportion of 1 : $2\frac{1}{2}$: 5. Concrete mixed in this proportion requires about three tenths of a barrel less cement than 1 : 2 : 4 mix. Figuring cement at \$2 per bbl., concrete mixed in the proportion of 1 : $2\frac{1}{2}$: 5 works out at approximately 32 cents per cu. ft. in place.

In calculating the amount of materials necessary to make 1 cu. yd. of concrete, it will be noticed that the only change made in the quantities for the various mixes has been in the amount of cement used. It has been assumed that a cubic yard of 1 : 1 : 2 concrete will require the same quantity of sand and crushed stone as a cubic yard of 1 : 2 : 4 concrete. Theoretically this is not true, but in general practice there is some waste of material and it has been found that the small differences of aggregate used in the various mixes of concrete in a building are negligible. A very large part of the concrete in a building is a 1:2:4 concrete, therefore the aggregate quantities of 1:2:4 mix are generally used for all concrete work, and the cement alone is changed for various mixes. It will also be noted that the quantity of cement, sand and stone used here is somewhat in excess of the amount usually given in the tables published in various text-books. It must be borne in mind that the waste of materials on the job must be absorbed, and the quantities in tables compiled by laboratory tests must be somewhat increased. It is actually necessary to estimate on about $1\frac{2}{3}$ bbl. of cement to make 1 cu. yd. of 1:2 : 4 concrete on a job where the usual construction methods are employed, and in other mixes of concrete the cement should be proportionately increased.

The prices of concrete work as tabulated here are about 30 per cent. in excess of pre-war prices and 50 per cent. more than

the prices of 1913. These costs based on the present high cost of material and labor should be adjusted from time to time as necessary.

"*Plant.*"

In making estimates for the cost of concrete in place, the most uncertain element entering into this cost is the item of "plant." The cost of "plant and tools" varies greatly with different contractors, and depends largely upon the foresight of the persons responsible for the layout of the job operations. The number and location of the mixers, towers and runs used on the job, layout and extent of storage space for aggregate, source and expense of power, etc., distance over which concrete machinery has to be transported, good or bad mechanical conditions of rented machinery, rental rates of machinery, replacement of missing shovels and other tools, and many other variable expenses go to make up this cost. The size and shape of the building, as well as the speed of the operations, play an important part in this cost. The "plant" cost for a job containing 6 000 cu. yds. of concrete need not necessarily be one-fifth more than a job containing 5 000 cu. yds. of concrete. The "plant" will, of course, cost more for the job containing 6 000 cu. yds. of concrete, but since the cost of erecting and dismantling the "plant" work for both jobs may be the same, the extra cost of "plant" for the larger job will be principally extra depreciation or rental, fuel, power, wear and tear, and loss of tools. However, "plant" expense enters into all concrete costs, and must be included in the unite price of concrete if we would get a reasonably accurate idea of the ultimate cost of the work. At the present high cost of all building materials and labor, "plant" costs cannot be safely assumed to be less than $1 per cu. yd. and will very seldom run as high as $2 per cu. yd. of concrete. Owing to this wide variation in the cost of "plant," it is necessary in estimating concrete to strike an average cost which, while not accurate, will cover the usual "plant" work, and give a unit cost for concrete in which all items of material and labor have been considered. It is with this in view that a "plant" cost of $1.25 per cu. yd. has been used in making up the unit cost of concrete in place as given in the above tabulation.

Steel Reinforcement.

The cost of steel reinforcement is extremely erratic in its fluctuation, but at present it may be assumed at $90 per ton, exclusive of the labor of bending and placing. It will cost from $6 to $15 per ton to cut, bend and place this reinforcement, $100 per ton, or 5 cents per lb., being a unit price which may be used to give reasonably close cost ratios. Reinforcement requiring much bending and made up of small bars should be figured about one half cent per lb. higher than steel requiring only a small amount of bending. Spiral reinforcement for columns should be figured at an extra cost of about one-half cent per lb. over and above plain bars. In estimating the weight of spiral reinforcement it should be remembered that about 7 per cent. should be added to the weight of the spirals for welding laps. Also, it will be necessary to add about 3 lbs. per lin. ft. of column for spacers used to hold the spirals in proper pitch.

Forms.

Forms for round columns are usually made from sheet metal, and in flat slab construction it usually works out cheaper to use round interior columns formed with this material. However, the cost of forming an interior column 26 ins. in diameter for flat slab construction is about the same as forming a column 20 ins. in diameter designed for the same purpose. This being the case, it is not necessary to consider the difference in the cost of forms due to different diameters of round interior columns. It may be well to remember that it costs somewhat less to build an interior column having a head by using a steel form than it does to form the column of wood, as the cost of forming the head in wood is no small part of the column cost. The list of unit prices given here covers the cost of labor and material for form work for the principal operations in a concrete building, but are tabulated for use in making comparative estimates only. It must be borne in mind that these unit prices are for the use of the engineer in weeding out the more expensive designs, and are not to be used for making actual estimates of buildings without regard to conditions and what not. While these costs might be more or less useful in arriving at the total cost of a concrete

building, it should be remembered that they are only approximate units to be used for the purpose outlined herein.

Type of Construction.	Sq. Ft. Cost. (Surface Measurement.)
Forms for flat slabs, including drop panels	$0.09
Slab, beam and girder construction, slabs to span not less than 9 ft.	.12
Slab, beam and girder construction, slabs to span not less than 7 ft.	.13
Slab, beam and girder construction, slabs to span not less than 5 ft.	.14
Column forms	.15
Floor beams and girders, not including slabs	.16
Wall beams	.14
Partitions and wall forms	.15
Footing and foundation forms	.15
Round steel column forms, including heads, each	15.00

Estimates Made from Cross-Sections.

Now that the methods of arriving at the comparative costs of the various types of concrete construction have been outlined, it is believed the designer will be able to work more intelligently regarding the cost his work involves. Typical dimensioned sketch cross-sections of the building from the roof slab to the footings should be made, and the work of estimating done from these sketches. In this way the extra column lengths required to obtain the same clearstory heights will enter into the estimate. This is quite a factor in comparing flat slab with beam and girder designs. Estimates made from these cross-sections for a length of building equal to one bay only, is the usual practice. In this way the cost per linear foot of building as well as the cost per square foot of floor space may be calculated. Comparisons of costs made in this manner are genuine proofs to the designer that he is giving the design proper study for economy, and will result in a conservation of building materials, save good dollars for the owner, and establish for the engineer the reputation of being a designer of economical concrete buildings.

Part II.

Columns.

Probably no part of a concrete building is simpler to design than the columns, and because of this simplicity the designer is very likely to give this part of his computations very little special

study. It is also true that no part of a concrete building can conceal so effectively the lack of economical design as can the columns.

The economical design of the columns for a concrete building of only one or even two stories in height, is not a matter requiring much special study, but in buildings several stories in height the subject is one of vast importance. It is not possible to design columns showing maximum economy without careful consideration of several important facts. Engineers designing concrete buildings realize that a richer mix of concrete costs more than a leaner mix. They realize that to offset this extra cost of a richer mix of concrete in column design, there is a corresponding decrease in reinforcement which results in a change in the total costs of the concrete columns. The manipulation of these mixes of concrete in order to determine the most economical column construction is a subject for real study, and to accomplish this end the engineer will find it necessary to make several trial designs and calculate the cost of each design. For example, a column 26 ins. in diameter, composed of concrete mixed in the proportion of $1 : 1\frac{1}{2} : 3$, reinforced with eleven 1-in. round rods and 1 per cent. spiral hooping, will carry about the same load as a column of the same diameter composed of $1 : 1 : 2$ concrete, reinforced with seven $\frac{7}{8}$-in. round rods and 1 per cent. spiral hooping. As both of these are good designs, the question arises as to which one would be the most economical. Assuming the unit price of $1 : 1\frac{1}{2} : 3$ and $1 : 1 : 2$ concrete at 36 cents and 43 cents per cu. ft. respectively, vertical reinforcement at 5 cents per lb., and spiral hooping at $5\frac{1}{2}$ cents per lb. in place, it can be clearly shown that the column composed of $1 : 1 : 2$ concrete will prove to be the more economical one to use. The point at which the column mixes change and where spirally reinforced columns should be used is determined only by making these comparative estimates.

It is not uncommon to see detailed plans calling for a lap in all the rods in a lower story column without regard to the fact that the column above may call for a lesser number of rods for its reinforcement, and it is only necessary to lap part of them. This is real waste, and shows careless design which will run into

money faster than the designer suspects. For illustration, the first-story wall columns of a concrete building are 36 x 34 ins., reinforced with twenty $1\frac{1}{8}$-in. round rods. The second-story wall columns are 36 x 30 ins., reinforced with fourteen $1\frac{1}{8}$-in. round rods. A lap of thirty diameters is called for in all column rods. If the entire twenty rods in a first-story column are lapped into the second-story column it means that six of these twenty $1\frac{1}{8}$-in. rods have been unnecessarily lapped and consequently this extra reinforcement wasted. Had only fourteen of these first-story column rods been lapped into the second-story column instead of twenty, a saving of about 17 lin. ft. of $1\frac{1}{8}$ in. round steel rod would have been made. This reinforcement, figured at 5 cents per lb., would have shown a saving of about $3 at this one point. Multiply this saving by the number of columns in the building where such laps occur and it becomes no small item. The expense of a case of this kind becomes considerably greater when the column in question is a wall column on which is superimposed a so-called turned-up wall beam designed to be poured with the floor slab. In this case the specified lap begins at the top of the wall beam instead of the top of the floor slab and extends upward. For example, suppose a wall beam, extending 14 ins. above the second floor, designed to be poured with the slab, had been superimposed on the 36 x 34-in. wall column just discussed. In this case the lap must be measured from the point where pouring is stopped. If the twenty $1\frac{1}{8}$-in. round rods are all carried up into the second-story column for a lap of 30 diameters it means that all the rods must extend to a point 4 ft. above the second floor, when in reality it is necessary to carry only fourteen of these rods to this point, starting the fourteen $1\frac{1}{8}$-in. round rods in the second-story column at a point 14 ins. above the second floor and extending upward. The loss incurred by carrying the entire twenty $1\frac{1}{8}$-in. round rods into the second-story column is about 24 ft. of $1\frac{1}{8}$-in. round rod, which at 5 cents per lb. is about $4, as against the loss of $3 when no wall beam is designed to be poured with the floor slab. Wastes of this nature, at the present high price of reinforcement, are serious.

In the design of wall columns it will be necessary, usually,

to consider the amount of sash and curtain wall required to fill the space between columns, as the smaller the width of the exterior columns the more sash and curtain wall will be required to fill in the space between these columns. This may seem trivial, but it will oftentimes give false impressions of economy if all these seemingly trivial details are not given a place in the estimated comparative costs of the various designs.

Illustrations of the methods of determining the economical interior column are given below. It may be well to add that no attempt is made to consider any of the various methods of concrete design from an engineering standpoint. This paper is not intended to be a text on design in any form, but rather it is intended to present to the designing engineer a method by which he can solve for himself the question of economy in his work. Hence, the reader should study the examples given here with a view of applying the methods of cost calculation to his work and not draw engineering conclusions from any of these illustrative costs.

Several comparative designs for any interior column (Fig. 1) are shown here. The comparative costs of the various schemes are worked out in detail, using unit prices principally from tabulations in Part I of this paper.

	Design.	Comparative Estimates.	
Scheme (a)	36-in. dia. col.	Conc. . . . . 99 cu. ft. at 34c.	$33.66
	11 $1\frac{1}{8}$ in. rd. vert. rods	Forms. . . . . Round steel.	15.00
	$\frac{3}{8}$-in. rd. bands 12 ins. o/c	Reinfct. . . . . 716 lbs. at 5c	35.80
	Mix 1 : 2 : 4	Lost floor space . 5 sq. ft. at $2.75	13.75
		Total.	$98.21
Scheme (b)	32-in. dia. col.	Conc. . . . . 79 cu. ft. at 34c.	$26.86
	23 $1\frac{1}{8}$-in. rd. vert. rods	Forms. . . . . Round steel.	15.00
	$\frac{3}{8}$-in. rd. bands 12 ins. o c	Reinfct. . . . . 1 437 lbs. at 5c	71.85
	Mix 1 : 2 : 4	Lost floor space. . $3\frac{1}{10}$ sq. ft. at $2.75.	8.53
		Total.	$122.24
Scheme (c)	2-in. dia. col.	Conc. . . . . 79 cu. ft. at $36\frac{1}{2}$c.	$28.84
	12 $1\frac{1}{8}$-in. rd. vert. rods. . . .	Forms. . . . . Round steel.	15.00
	$\frac{3}{8}$ in. rd. bands 12 ins. o c	Reinfct. . . . . 770 lbs. at 5c	38.50
	Mix 1 : $1\frac{1}{2}$: 3	Lost floor space. . $3\frac{1}{10}$ sq. ft. at $2.75.	8.53
		Total.	$90.87

Scheme	Design.	Comparative Estimates.		
Scheme (d)	26-in. dia. col.	Conc.	52 cu. ft. at $36\frac{1}{2}$c.	$18.98
	11 1-in. rd. vert. rods	Forms.	Round steel.	15.00
	1 per cent. spirals ($18\frac{1}{2}$ lbs.)	Reinfct. (vert.)	514 lbs. at 5c	25.70
	per lin. ft.	Spirals.	264 lbs. at $5\frac{1}{2}$c	14.52
	Mix 1 : $1\frac{1}{2}$: 3	Lost floor space.	$\frac{7}{10}$ sq. ft. at $2.75	1.92
		Total.		$76.12
Scheme (e)	28-in. dia. col.	Conc.	$60\frac{1}{2}$ cu. ft. at 43c.	$26.02
	20 $1\frac{1}{8}$-in. rd. vert. rods.	Forms.	Round steel.	15.00
	$\frac{3}{8}$-in. rd. bands 12 ins. o/c	Reinfct.	1 255 lbs. at 5c	62.75
	Mix 1 : 1 : 2	Lost floor space.	1.45 sq. ft. at $2.75	3.99
		Total.		$107.76
Scheme (f)	26-in. dia. col.	Conc.	52 cu. ft. at 43c.	$22.36
	7 $\frac{7}{8}$-in. rd. vert. rods	Forms.	Round steel	15.00
	1 per cent spirals ($18\frac{1}{2}$ lbs.)	Reinfct.	245 lbs. at 5c.	12.25
	per lin. ft.	Spirals.	264 lbs. at $5\frac{1}{2}$c	14.52
	Mix 1 : 1 : 2	Lost floor space.	$\frac{7}{10}$ sq. ft. at $2.75	1.92
		Total.		$66.05
Scheme (g)	24-in. dia. col.	Conc.	$44\frac{1}{2}$ cu. ft. at 43c.	$19.14
	10 $1\frac{1}{8}$-in. rd. vert. rods	Forms.	Round steel.	15.00
	1 per cent. spirals (16 lbs.)	Reinfct. (vert.)	606 lbs. at 5c	30.30
	per lin. ft.	Spirals.	229 lbs. at $5\frac{1}{2}$c	12.60
	Mix 1 : 1 : 2			
		Total.		$77.04

From the above estimated comparative costs, perhaps the most noticeable fact is that the columns using the 1 : 2 : 4 mix of concrete are among the most expensive. Using this lean mix necessarily produces a column larger in diameter, which means, also, a loss of valuable floor space. It will also be noticed that the smallest column designed is not the most economical. The column which shows the most economy in this case is one having a 1 : 1 : 2 mix and about 1 per cent. of vertical reinforcement, together with 1 per cent. of spiral reinforcement. Hence, a rich mix of concrete and comparatively small percentages of steel reinforcement seem to show the most economical results for a column carrying a fairly heavy load.

For comparative purposes, the difference in the amount of concrete in the column heads may be neglected, as the top diameter of the head usually remains the same throughout the building. The cost of forming the column and its head has been estimated here at $15 each. This is done for convenience in

arriving at a total cost of the column shaft. Ordinarily this cost is neglected in making comparative estimates of interior round columns, as it costs about the same to form a round column of small diameter as it does a column of larger diameter. Many other schemes may be designed for this particular column, and the comparative costs estimated. However, these several examples, some of which are obviously too expensive to consider, will suffice to give the reader a working knowledge of the methods of calculation employed to determine the costs of the various types of interior columns. It is readily appreciated that even though a larger column were somewhat cheaper to build, the additional floor space occupied by this larger column might be worth more to the owner of the building than he would save in the construction of the column. Hence, it becomes necessary to consider the value of this additional floor space as a part of the cost of this larger column. It is difficult to say just what this floor space is really worth. However, a satisfactory way to deal with the situation is to consider the smallest column designed as a basis to which the other columns are to be compared. In the above illustration this column is 24 ins. in diameter. Consider the area of floor space occupied by a column equal to the square of the diameter of the column. The additional area occupied by any one of these larger columns is equal to the difference of the square of the diameter of the column in question and the square of the diameter of the smallest column design. This additional or lost floor area is priced at a unit cost equal to the approximate unit cost per square foot of floor space of the completed building including heating, lighting, sprinklers, etc. The unit cost per square foot of building is calculated by dividing the approximate total cost of the building by the number of square feet of floor space in the building, measurements to be taken "out to out" of the floor plan. For example, a building 200 x 60 ft. and five stories high may cost \$165 000 complete. This works out at \$2.75 per sq. ft., and for general purposes this will give fairly accurate results for the purpose described above.

In the comparative estimates of the interior column (Fig. 1) given, if we strike out of each estimate the cost of lost floor space, the relative cost of each column will remain unchanged. This

is not always the case, and even in our examples it will be noticed that the columns having the leaner mixes show up much more favorably when this item of cost is excluded from the total cost of the column. Frequently, the omission of this item will result in a transposition of the economic order of the various designs. In many buildings the loss of a few feet of floor space is immaterial, but in other cases it is of great importance, as in storehouses or in buildings where the machinery layout would be interfered with by a larger column. Where loft buildings or

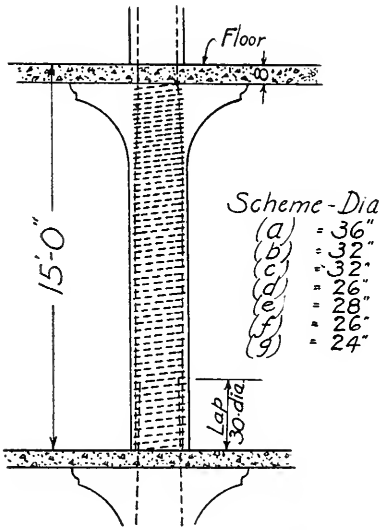


FIG. 1. INTERIOR COLUMN.

offices are rented by the square foot of net area the cost of this floor space should be figured at a considerably higher figure than the one given in our tables.

In determining the economical wall column, the method is very similar to that used for interior columns except that the item of the cost of wood forms enters into the estimate. It will be necessary also in designing exterior columns to consider the width carefully, as every inch added or deducted to the width of the column will change the corresponding dimension of wall sash a like amount.

Consideration is given below to the economical design of a typical wall column (Fig. 2) for a concrete building having these columns spaced 20 ft. on centers. For lack of space only three designs will be compared here, but the principles are clearly illustrated, and further designs should be treated in a like manner.

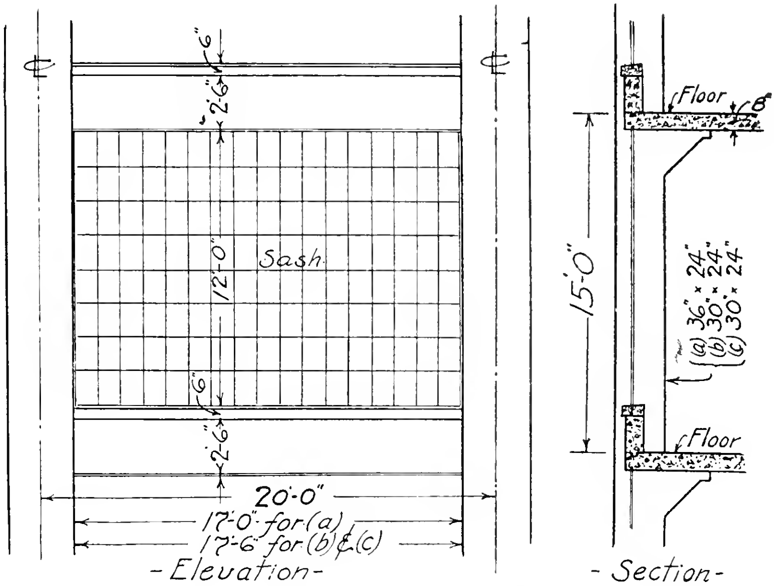


FIG. 2. TYPICAL WALL COLUMN.

Design.		Comparative Estimates.	
Scheme (a)	36 x 24 ins.	Conc............86 cu. ft. at 34c........	$29.24
	12 $\frac{1}{8}$-in. rd. rods 17 ft. 6 ins.	Forms..........143 sq. ft at 15c.......	21.45
	$\frac{3}{8}$-in. rd. bands 12 ins. o/c	Reinfct..........777 lbs. at 5c...........	38.85
		Curtain walls....31 sq. ft. at 75c........	23.25
		Window sill......17 lin. ft. at 60c........	10.20
		Sash and glass...204 sq. ft. at 45c.......	91.80
		Total...........................	$214.70

Design.		Comparative Estimates.	
Scheme (b)	30 x 24 ins.	Conc...........$71\frac{2}{3}$ cu. ft. at $36\frac{1}{2}$c......	$26.16
	101 $\frac{1}{8}$-in. rd. rods 17 ft. 10 ins.	Forms..........129 sq. ft. at 15c.......	19.35
	$\frac{3}{8}$-in. bands 12 ins. o/c	Reinfct.........651 lbs. at 5c..........	32.55
	Mix 1 : $1\frac{1}{2}$: 3	Curtain walls....32 sq. ft. at 75c........	24.00
		Window sills.....$17\frac{1}{2}$ lin. ft. at 60c.......	10.50
		Sash and glass...210 sq. ft. at 45c.......	94.50
		Total...........................	$207.06

	Design.	Comparative Estimates.	
Scheme (c)	30 x 22 ins.	Conc. . . . . 46 cu. ft. at 43c.	\$19.78
	12 $\frac{7}{8}$-in. rd. rods 17 ft. 2 ins.	Forms. . . . . 124 sq. ft. at 15c.	18.60
	$\frac{3}{8}$-in. rd. bands 12 ins. o/c	Reinfct. . . . . 460 lbs. at 5c	23.00
	Mix 1 : 1 : 2	Curtain wall. . . . . 32 sq. ft. at 75c.	24.00
		Window sills. . . . . $17\frac{1}{2}$ lin. ft. at 60c.	10.50
		Sash and glass. . . 210 sq. ft. at 45c.	94.50
		Total.	\$190.38

The cost of each wall column design includes the cost of sash and glass together with the curtain wall necessary to fill in one bay. For convenience in making these estimates, it is assumed the glass is factory ribbed glass costing 20 cents per sq. ft., including glazing. Steel sash is estimated here at 25 cents per sq. ft., erected and pointed, making a total of 45 cents per sq. ft. for the sash and glass in place. The curtain wall below the sash is figured here at 75 cents per sq. ft. In making the sketches of the exterior wall bay for estimate purposes, no care has been exercised to select stock sizes of steel wall sash. In actual practice, however, this is usually of prime importance. The cost of the extra floor space occupied by the larger wall column has not been considered here, as its influence on these particular columns would be negligible.

Footings.

In the design of concrete footings it often happens that it is difficult to decide offhand whether a plain or reinforced concrete footing should be used. A design of each type of footing should be made and the comparative costs calculated. The engineer knowing the kind of soil these footings will rest upon should price the excavation required at a proper figure. This is a very important part of the footing cost, in fact, many times the most vital part of the estimate for foundation work. In the absence of any more reliable information, the unit costs of excavation per cubic yard (not over 5 ft. deep) may be assumed as follows:

Loam or other easy excavation	\$0.75 cu. yd.
Gravelly earth containing small stones	\$1.00– 1.50 cu. yd.
Frozen earth	2.25– 2.50 cu. yd.

Rock or ledge excavation	$3.50– 4.00 cu. yd.
Backfill	.30– .50 cu. yd.
Sheeting around excavated holes for footings	.10 sq. ft.

For excavation work over 5 ft. deep and down to 10 ft. deep, the unit cost on the yardage below the 5-ft. depth should be increased approximately 50 per cent. An example is given below with comparative costs for the two types of footings, reinforced and plain, shown in Fig. 3 and Fig. 4, respectively.

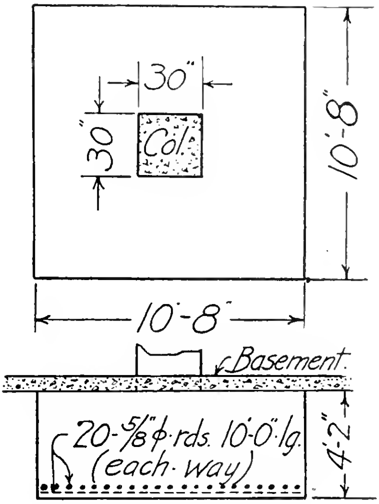


FIG. 3. FOOTING. SCHEME (a).

The excavation is assumed as costing $1 per cu. yd. to remove, and the excavated holes are sheeted close in order to do away with form work around the large footing block.

Scheme (a) Reinforced type (mix 1 : 2 : 4)	Conc	460 cu. ft. at 34c	$156.40
	Forms (none).		
	Reinforcement	420 lbs. at 5c	21.00
	Excavation	$19\frac{1}{4}$ cu. yds. at $1.00	19.25
	Backfill and level	$19\frac{1}{4}$ cu. yds. at 30c	5.78
	3-in. (close) sheeting	182 sq. ft. at 10c	18.20
	Total		$220.63

Scheme (b) Plain type	Concrete 1 : $2\frac{1}{2}$: 5 .... 507 cu. ft. at 32c.	\$162.24
	Forms (top block) .... 84 sq. ft. at 15c.	12.60
	Excavation .... 24 cu. yds. at \$1.00	24.00
	Excavation below 5-ft. mark. $5\frac{1}{2}$ cu. yds. at \$1.50 ..	8.25
	Backfill and level .... $29\frac{1}{2}$ cu. yds. at 30c. .	8.85
	3-in. (close) sheeting .... 270 sq. ft. at 10c. . .	27.00
	Total	\$242.94

As above shown, the reinforced footing is the most economical to use in this case. However, provided stones or "plums"

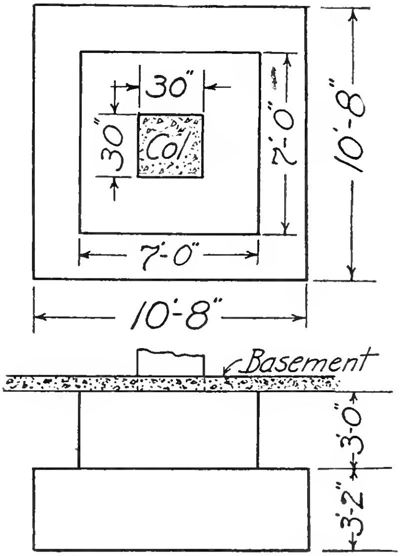


FIG. 4. FOOTING. SCHEME (b).

were obtainable at a small expense, the cost of the plain footing could be considerably reduced. It will be noted in the estimates for these two footings that the excavation for the plain footing is the determining factor in its cost. The materials used in the plain footing cost somewhat less than those used in the reinforced type, but the extra depth of the excavation makes the plain type the more expensive one to use. This extra cost becomes still greater when the footings are placed in wet or frozen

ground, for which excavation costs are considerably more. In case the reinforced type of footing is built with a sloping top, and a wood form is used for this top, the cost would be about the same as though the concrete were poured up to a level with the top of the footing, and the form work omitted, as above estimated. In some operations the top part of a footing is sloped and the concrete poured "dry." This necessitates a change in the batch, slows up operations, and many times does not work out economically. For estimating comparative costs of footings it is not a safe procedure to assume that the top part of the footing will be poured "dry" in order to do away with forms on the slope. Either estimate a form for this sloping surface or figure on the concrete as being poured up to a level with the top of the footing.

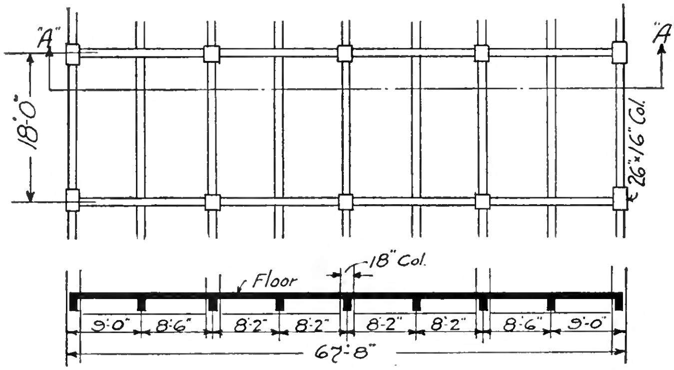
Beam and Girder Floors.

It has been previously stated that, in the design of the beam and girder type floor, the omission or addition of one intermediate beam per bay may influence the cost materially. Although this problem is usually handled economically by engineers designing concrete buildings which have usual floor loadings and column spacings, it sometimes happens that when unusual floor loadings and column spacings are required, it is necessary for the engineer to determine a layout which will show the most economy. In a proposition of this kind it is first necessary to make the design which looks most likely to be the economical one. Then two more designs should be made, one having one more intermediate beam and the other having one less intermediate beam. Sometimes the girders should be run in other ways and designs made on layouts entirely dissimilar. Cost comparisons made of these designs will show conclusively which system should be adopted.

For the purpose of illustrating the methods of estimating beam and girder floors with a view to economy, the two schemes shown in Fig. 5 and Fig. 6, designed for the same column spacings and live loads, are estimated here in a comparative way. Only these two layouts are compared here, but other layouts should be estimated in a similar manner, bearing in mind that

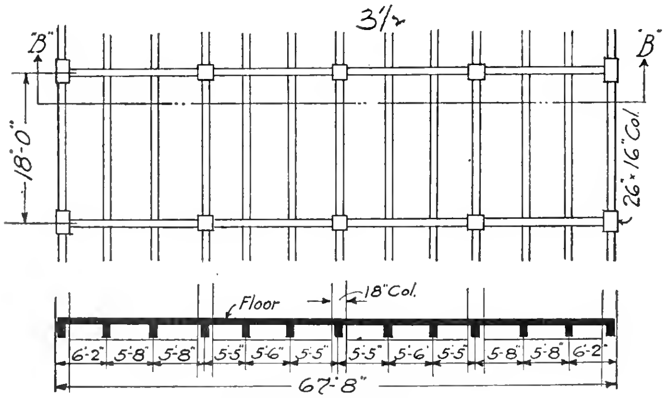
the more beams and girders in the floor the more expensive the form work becomes.

In scaling the quantities for the comparative estimates of these two designs, it will be necessary to include all the concrete



Cross Section A-A.

Fig. 5. Beam and Girder Floor (Scheme 1).



Cross Section A-A.

Fig. 6. Beam and Girder Floor (Scheme 2).

forms and steel reinforcement in one 18-ft. bay for the full width of the building, which is about 67 ft. 6 ins. In Fig. 5 the quantities will include the slab over one complete bay, 7 intermediate beams, 2 wall beams, and 4 girders. In Fig. 6, the corresponding quantities will include the slab over one complete

bay, 11 intermediate beams, 2 wall beams and 4 girders. Below, under the head of "Estimate, Fig. 5," and "Estimate, Fig. 6," will be found these respective quantities to which unit prices have been fixed (a list of which will be found in Part I), and the total comparative cost of one bay for each scheme estimated.

Estimate, Fig. 5.		Estimate, Fig. 6.	
Concrete, 825 cu. ft. at 34c..	$280.50	Concrete, 700 cu. ft. at 34c..	$238.00
Forms, 1 860 sq. ft. at 13c...	241.80	Forms, 2 000 sq. ft. at 14c..	280.00
Reinfct., 7 300 lbs. at 5c....	365.00	Reinfct., 6 300 lbs. at 5c....	315.00
Total..................	$887.30	Total.................	$833.00
(Unit cost, 73 cents sq. ft. of floor)		(Unit cost, 68½ cents sq. ft. of floor)	

In "scaling off" the quantities for comparative estimates of beam and girder type floors, care must be taken to carefully consider the laps in the reinforcement. All steel reinforcement actually occurring in the slab and beams should be estimated. In taking off the quantities, also, it will be found most convenient to first get the quantity of concrete, then the square feet of forms, and lastly the pounds of reinforcement. The order of scaling for the form work and reinforcement should be the same as that followed in getting the quantity of concrete, that is, if beams follow slabs in the concrete scaling, beam steel should follow slab steel in the reinforcement scaling. This method will eliminate to a large extent the liability of error, and also lessen the work of scaling dimensions since the form areas may be taken directly from the scaled dimensions of the concrete work.

The slight changes in column and footing design which might actually occur in two buildings designed with floors like those above estimated, have not been considered here, as the details of column and footing costs are treated elsewhere. However, in buildings several stories in height, this phase of the design should be carefully considered in conjunction with the cost of floor designs when the cost comparisons are made. Even though the spacing of columns remains the same for all schemes considered, the different dead loads may influence the cost of the columns and footings considerably, and the different girder depths may make it possible to vary the over-all height of the columns in order to get the same clear head room.

Flat Slab Floors.

Flat slab floor construction is fast replacing the beam and girder type of floor, and, generally speaking, has advantages in appearance and economy. However, there will be places where the beam and girder system will show a lower cost. Where panels between columns are square or nearly so, the flat slab usually works to advantage. When columns are spaced unequally or irregularly, it is often more economical to resort to the beam and girder type of floor. If the column spacings may be laid out with economy in view, the square bay and the flat slab will generally be selected. However, this selection should not always be made without a proper check by comparative cost estimates. Assuming, for instance, that a concrete storage building is required, the width of which may be anywhere from 55 to 65 ft. and sufficient in length to give a certain specified area of floor space. The design is to be a flat slab system, and the building is to be built as economically as possible. The engineer will usually make a design for a flat slab system with the columns spaced at distances he believes will show economical results. He should now make two more flat slab designs with the column spacings one foot more and one foot less respectively. Comparative costs made on these three designs will show him the economical standing of the various spacings for the specified live load, and if it does not show him definitely which spacing to use it will give him the hint as to which extreme of column spacings he must still continue to design. It will be necessary to make typical cross-section designs showing the column spacings considered and then calculate the comparative costs of each design for a length of building equal to one bay. It is a simple matter to calculate the number of bays necessary for each type of cross-section to deliver the required amount of building floor space. This being done and the cost of one bay of each type of building being already calculated, the total approximate cost of each type of building is easily found. Adding to these respective estimates the cost of closing in the two extreme ends of the building, the engineer has a very good idea of the comparative costs of the designs he has made.

Special Problems.

The principal elements going to make up the cost of a concrete building have been briefly touched upon, with a few illustrations of the methods of making cost comparisons. It is believed the designer will now be able to cope with special problems in a smaller manner, always trying to make actual cost comparisons bear out his decisions whenever it is possible to do so.

The use of rods $\frac{11}{16}$, $\frac{13}{16}$ and $\frac{15}{16}$ in. in diameter should be discouraged, as it is difficult to obtain these sizes. When these unusual sizes appear on the plans, the party estimating the job is likely to protect himself by estimating the reinforcement at an increased cost.

Care should be taken to so design the roof beams that the width will be the same as those in the floor below. By doing this it makes it possible to use the same forms for the roof as were used for the floors, the only change necessary being made on the beam bottoms, which will be raised somewhat to form a beam of less depth.

Effect of Local Conditions on Cost.

The locality of the job in hand plays an important part in the design and cost of the work. Cost comparisons should not be made without regard to this special consideration. Low-priced gravel may take the place of sand and crushed stone. Cement may be unusually cheap owing to very low freight rates. Sand may be procured from a sand bank nearby or possibly from the footing excavation. Crushed stone may be had from a crushing plant close to the site of the job or it may be excessively high in cost. Reinforcement costs may be extremely high on account of transportation. Any one or all of these conditions would influence all concrete units. These local conditions and the prices should be studied by the engineer before starting his design. If he does not do so his cost comparisons may not, after all, lead to the correct conclusions.

It was found, in making comparative estimates of two systems of floor construction, that when the quantities were priced at the rates prevailing in Buffalo the costs of the two designs were about the same. When New York City prices were applied to

the same designs a saving of about 8 per cent. of the cost was shown in favor of the design calling for the least concrete and the most reinforcement.

Fluctuation of Unit Costs.

Unit costs of labor and materials for all classes of building construction are constantly changing, and it is hardly to be expected that one whose business is not entirely estimating be kept well informed of the many fluctuations. However, it has been shown in this article that the designer does have to use absolutely accurate unit costs in order to determine by comparative estimates the relative economic standing of his designs. A review of the market conditions from time to time in a general way will give him enough information to revise his unit costs in order that his comparisons may show more accurately the true status of his work. The prices tabulated and used throughout this paper, as before mentioned, are much higher than the prices of two or three years ago. It is quite possible that two years hence they may undergo another change, equally great, and the engineer must look out for this and act accordingly. Five years ago the ratio of cost of concrete, forms, and steel in a building was roughly 2 : 2 : 1. To-day it is about 2 : 1 : 1 — that is to say, five years ago the total cost of the concrete about equaled the cost of the forms, and the reinforcement equaled about one half of the cost of either. To-day the cost of the concrete in a building is slightly less than twice the cost of the forms and the reinforcement is about equal to the forms. It is quite probable that five years from now the ratio may be again changed.

Conclusion.

In this paper many designs might have been made and the comparative cost of each design calculated. Building layouts might have been discussed at length with a view to economy of construction. Economical column spacings for flat slab designs for various live loads could have been worked out. However, with the engineer governed largely by specific conditions, building laws, fiber stresses, etc., it would be difficult indeed to cover

the subject, even in a general way, in a paper many times the size of this one. Therefore, it was thought best to give most of the space to methods of estimating the comparative costs of the principal members which go to make up a concrete building, and not deal specifically with the layout of the building. Again, mention is made of the fact that the designs and quantities used here to illustrate the methods of comparative cost estimating are in no way to be viewed from an engineering standpoint. These examples are intended to be of value only in so far as they serve for illustrative purposes, and must not be considered as solutions to engineering problems. It is not within the scope of this paper to lay down rules for concrete design, but rather define and illustrate principles by which the accepted rules may be economically applied. If the engineer has in hand the application of these principles he can solve the question of economy in his layout for himself.

In writing this paper, it is not intended to try to make building estimators of all designers of concrete buildings. It is, however, hoped that it will arouse the interest of the designer to a keener desire to know the cost of his designs, and to promote the practice of comparative cost estimating among designing engineers. Such practice, if conscientiously followed, will be extremely helpful in enabling the designer to choose wisely, and at the same time imbue him with a new confidence that his work really contains the most economical methods to achieve his purposes. He will get a new perspective of his work and develop to a greater degree the capacity for thinking in dollars and cents as well as in stresses and strains. His work will become more interesting and his services of more value. It was with this in view that this paper was conceived, and the effort will be well worth while if this purpose has, even in a small way, been accomplished.

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PAPERS AND DISCUSSIONS

SEWER PIPE JOINTS.

BY J. LESLIE WOODFALL, EDWIN H. ROGERS, HENRY A. VARNEY, LEWIS M. HASTINGS, BERTRAM BREWER, FRANK A. MARSTON AND GEO. A. CARPENTER.

(Topical Discussion presented before the Sanitary Section, January 2, 1918.)

J. LESLIE WOODFALL.* — The question of making satisfactory joints in sewer pipe is one which has given engineers considerable trouble, and one which has been a subject of experiment for a great many years.

This subject may be divided under two headings: first, the form of the pipe or joint; and, second, the material to be used in making the joint.

Cement pipe is manufactured with two forms for the joint. In the first, the ends of the pipe are beveled for a short distance, so that the end of one pipe can be forced or placed in the end of the other. The second is the regular bell and spigot pipe.

Vitrified pipe is also made in two forms, viz., ring pipe and bell and spigot pipe.

In the early nineties dissatisfaction among engineers on account of the small space allowed for making the joint resulted in the manufacture of the so-called deep and wide socket pipe. I believe this pipe was first manufactured by the Portland Stoneware Company, from drawings furnished them by M. M. Tidd, civil engineer, of Boston.

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This form of bell was soon made by all of the manufacturers, but for reasons of cost a compromise bell was adopted which is now manufactured under the name of Standard Pipe.

During the last few years some of the manufacturers have adopted the making of the deep and wide socket pipe exclusively, and the tendency appears to be towards this size of bell.

Method of Making the Joint.

Joints in sewer pipe, until recent years, have been made mostly with cement. I have been informed that in England well-puddled clay was used to a considerable extent; also the so-called Stanford joint. This latter joint, I believe, was patented and was never extensively used in this country. It was made by filling the inside of the bell with a hot mixture similar to asphalt. The outside of the spigot was then chipped so as to allow it to be covered for a short distance with this same mixture. Molds, made so as to give a beveled surface, were used for pouring the material, and the pipes were forced together, thus making a tight joint. I understand some pipe was manufactured with the spigot end made so as to avoid the chipping.

Cement Mortar Joints.

Different methods of making cement joints are: first, by the use of cement mortar alone; second, by calking a gasket, either dry or soaked in liquid cement, into the bell and then filling the bell with cement; third, by placing the cement in the joint and then calking the gasket in, thus forcing the cement into the bell; and fourth, by the use of cement alone, forcing it thoroughly into the joint with a calking iron and covering the joint with cheesecloth for the purpose of holding the cement in place. In this latter joint small wooden blocks are imbedded in the cement of the bell for the purpose of centering the pipe.

An additional precaution to make the joints tight was used at Malden. This consisted in the use of a small wooden box having the sides cut to the radius of the outside of the pipe, which was placed at the joint and filled with cement mortar up to the middle of the sewer pipe. I used this method a number of years ago, but it did not prove entirely satisfactory.

Poured Joints.

Under this head may be included all of the methods of pouring the joints with hot mixtures. These mixtures are of two distinct classes, viz., that known variously as G–K, Jointite, etc., and that composed of sulphur and sand.

For making any of these joints, deep and wide socket pipe should be used. A gasket is first calked into the bell in a thorough manner, to prevent the material from running into the pipe. A gasket is then clamped around the pipe and the hot material poured in the same manner as in making water pipe joints.

Water must be kept out of the bell while the sulphur and sand joint is being poured. It is claimed that with G–K, or Jointite, this is not necessary, but from such information as I have obtained I judge it is difficult to make a good joint under water. The sulphur and sand joint becomes hard at once, but it is so rigid that the pipe will break if any settlement takes place. The G–K or Jointite compounds do not harden so quickly and have enough elasticity to take care of any slight settlement of the pipe.

In my experience covering thirty years, I have seen three small cases of broken sewer pipe. In one case the joint was made with cement while in the other cases sulphur and sand was used.

Careful levels indicated that the breaks were not caused by a settlement of the pipe.

Among the reasons for building sewers as nearly water-tight as possible are the following:

First, to avoid increasing the size of the sewers to provide for an extreme leakage; second, to prevent the pumping of an unnecessary amount of ground water; third, to prevent the treatment of an increased amount of sewage caused by the leakage of ground water into the sewers; and fourth, to prevent the entrance of tree roots in the sewers through imperfectly made joints.

In order to give an idea as to the relative merits of the different methods of making joints in sewer pipes, as herein described, I will give a record of the leakage in four towns in

which we measured the leakage immediately after we had built the sewers.

Easthampton, Mass., in 1893.

The joints were first calked with oakum which had been soaked in liquid cement and then filled with cement mortar. The leakage in about $1\frac{1}{4}$ miles was at the rate of 55 000 gals. per mile per 24 hrs.

Andover, Mass., in 1898.

The joints were made with cement mortar, which was first placed in the bottom of the bell of the pipe. Two small wooden blocks were then placed in the cement for the purpose of centering; the spigot of the next pipe placed in position, and the remainder of the joint filled with cement mortar calked with a calking iron, and the whole surrounded with cheesecloth. The leakage in 5.48 miles was at the rate of 5 912 gals. per mile per 24 hrs.

Amesbury, Mass., in 1912.

The joints were made with sulphur and sand. The leakage in $3\frac{1}{2}$ miles was at the rate of 9 700 gals. per mile per 24 hrs.

Lexington, Mass., in 1915–1916.

The joints in the vitrified sewer pipe were made with sulphur and sand, and in the iron pipe with lead. Measurements were made at two points: first, at the connection of the outlet sewer with the Metropolitan sewer, and second, at the upper end of the outlet sewer.

The outlet sewer is a little over 2.6 miles in length, of which a little over one half mile is vitrified pipe and the remainder is iron pipe. The length of sewers above the upper end of the outlet sewer is a little over 3.9 miles, and the joints were made with sulphur and sand. The leakage into the entire system of 6.56 miles as measured at the Metropolitan sewer was at the rate of 674 gals. per mile per 24 hrs., and for the 3.9 miles of the system above the upper end of the outlet sewer at the rate of 71 gals. per mile per 24 hrs.

Taking everything into consideration, my conclusions are that a nearer water-tight joint can be secured by pouring.

Edwin H. Rogers.* — The city of Newton, Mass., has a separate sewerage system, and for the past eleven and one-half years a sulphur and sand compound has been used exclusively as a jointing material for its vitrified pipe, sanitary sewers, and house connections, and for a limited amount of surface drains.

From June, 1906, to January, 1918, $28\frac{1}{2}$ miles of vitrified pipe sanitary sewers and $31\frac{1}{2}$ miles of vitrified pipe house connections have been laid with this compound of sulphur and sand. The total mileage of vitrified pipe sanitary sewers is now 118 miles, thus making 24 per cent. the proportion with the sulphur compound; and the total mileage of house connections is now $98\frac{1}{2}$ miles, thus making 32 per cent. of the house connections laid with this material.

The size of the pipe sewers so jointed varies from 8 ins. to 20 ins., but 89 per cent. of these sewers are 8-in. laterals. The house connections are 5 ins. with a few cases of 6 ins.

The method of making the joints in the pipes is similar to the pouring of lead joints in water mains. After fitting any two pipes closely together, the joint is calked with jute oakum, usually about $\frac{1}{2}$ in. to 1 in. in depth, but only sufficient to prevent the jointing material from running into the interior of the pipe. A pipe jointer is then placed around the outside of the spigot end of one pipe close against the bell of the adjacent pipe, leaving a triangular opening on top of the pipe through which the joint is poured full with the moulton mixture of sulphur and sand. A ladle large enough to hold sufficient material to pour the joint completely full at one operation should be used, and sufficient time given for the sulphur and sand compound to harden before removing the pipe jointer. After removing the jointer, the exposed surface of the sulphur and sand mixture is painted with hot roofing pitch to close up any possible voids or slight temperature cracks. It may be questioned if this practice is an absolute necessity, but the cost per joint is but slight, only about half a cent per joint, and is an added precaution for water tightness. The Tee branches provided for future house

* City Engineer, Newton, Mass.

connections are closed with a stopper held in place by roofing pitch, so as to be readily removed when necessary to make a connection with a house connection.

The sulphur and sand are mixed in equal parts by measure and melted together in an iron pot held in an iron frame and suspended over a fire of waste wood. Gasoline furnaces were previously used, but owing to the increased cost of gasoline the mixture is now heated by waste wood which is almost always to be found on a piece of sewer work. When gasoline was used for fuel for melting it required about .07 of a gallon of gasoline per joint.

The correct temperature to which the compound should be heated for use averages 260° F. The use of a thermometer is unnecessary after the workmen become accustomed to handling the mixture, as the correct temperature is easily ascertained by inspection. If it is too cold, it will not flow properly, and if too hot the tendency is to foam in the kettle. The use of the compound does not involve any waste material, for that which is left unused in the kettle is melted the next time it is wanted and fresh material added, together with any fragments left from defective joints from leakage around the jointer in pouring the joints.

The sulphur is powdered sulphur of commercial quality, bought by the barrel. The sand is a very fine quicksand, which is obtained from a pit on the city of Newton water-works reservation in the town of Needham. A great deal of the success of this type of joint depends on the fineness of the sand. Tests of the sand in use indicate that 90 per cent. will pass a sieve having 100 meshes per linear inch and 50 per cent. will pass a sieve having 200 meshes per linear inch. The pitch is ordinary roofing pitch. The jute is the usual type of tarred jute oakum. The pipe used is invariably deep and wide socket, as the annular space between the bell and spigot in standard pipe is considered too narrow for the best work.

The cost of sulphur varies from 2½ cents per pound in 1907, to 3 cents per pound in 1910, and 4.35 cents per pound in 1917. The sand is charged to each piece of work at the rate of $1 per barrel of 250 pounds or 0.4 cents per pound. The cost of the

jute varies from $5\frac{1}{2}$ cents per pound in 1918 to $8\frac{1}{2}$ cents and 10 cents per pound in 1917. The cost of the pitch varies from 1 cent per pound in 1908 to 1.3 cent per pound in 1917.

The quantities of material per joint required for 8-in. pipe are about as follows: sulphur, $1\frac{1}{2}$ lbs., sand, $1\frac{1}{2}$ lbs.; jute $\frac{1}{2}$ lb.; pitch, 0.4 lb. For 5-in. pipe the quantity of sulphur is about nine-tenths pound, and other materials in proportion. On the basis of present-day prices, the cost of materials for an 8-in. joint would be from 11 cents to 12 cents, but until recently the cost has been considerably less.

In 1907 a careful comparison was made of the cost of laying an 8-in. pipe sewer of 38 cement joints with an 8-in. sewer having 31 sulphur and sand joints. This test, which included the labor and materials for laying the pipe in both instances, showed a cost of 26.5 cents per joint and 23.8 cents respectively, or that the sulphur and sand joint cost 90 per cent. of the cement joint.

The advantages of the sulphur and sand joint appear to be many, and the following may be taken as the principal reasons for its use. When properly made, it is practically proof against leakage or infiltration and is entirely resistant to tree roots, while at the same time is not complicated and is readily executed. There appears to be no material difference between the cost of sulphur and sand joints and cement joints, and whatever difference there may be is a small percentage of the cost of the sewers. In laying pipe up to 8 in. in diameter inclusive, three lengths of 3-ft. pipe can usually be jointed on the bank, where a perfect joint can be made with great ease and then lowered into the trench, and, in the case of 10-in. or 12-in. pipe, two 3-ft. lengths can be so joined, whereas with cement joints the practice is to make every joint in the ditch. In other words, with the sulphur and sand joints in the smaller sizes of pipe, only 33 per cent., and in the medium sizes 50 per cent., are difficult of inspection, as against 100 per cent. with cement joints. It requires excellent workmanship and vigilant inspection to make sure that cement joints are properly made, particularly at the invert of the pipe, whereas the sulphur compound tends to run around the bottom of the pipe and make the joint most secure at this point. No difficulty is experienced in cold weather by the use of the

compound. In extreme weather and when the pipe is cold, it is easily heated by putting a string of tarred jute around the pipe at the joint and setting it on fire, thus heating the pipe sufficiently so that there is no difficulty in running the joint. After the joint is made, freezing weather will not hurt the sulphur compound, whereas cement joints should be protected from frost until the mortar is set. The time of setting of the sulphur compound is inconsiderable, for it is hard as soon as it is reasonably cool, whereas cement joints require a considerable period to harden.

Sulphur and sand joints are not flexible, but this is true of cement joints, and where there is a good foundation, non-flexibility in the sewer is no detriment in its construction. The sewer is usually placed at the lowest level of any of the structures in a street, and when it is laid in any material that provides a good foundation and is not susceptibile to settlement, there appears to be no disadvantages in a rigid joint, and in fact the rigid joint will frequently assist in maintaining the grade and alignment of the sewer.

The soil in Newton through which the sewers are laid is mostly hard pan, gravel, sand or ledge, there being but little subsoil of peat or of filling. The sewers are under constant inspection, and breakages are of very infrequent occurrence, there having been but two or three breaks in the 60 miles of pipe jointed with the sulphur compound since its use was adopted from settlement of the foundation of a sewer or house connection.

Trouble is frequently encountered from tree roots on nearly all of our sewers which are laid with cement joints in which there are trees along the side of the street, and the same is true of the older house connections laid with cement joints with trees in the near proximity. We have had absolutely no trouble from the growth of tree roots in sewers or house connections laid with sulphur and sand joints.

The sewage in Newton is largely from dwelling-houses, but no difficulty has been experienced with deterioration of joints from sewage from any of the comparatively few mills or factories, the sulphur and sand compound only being affected by

chemicals which are most rarely found in the trade wastes from manufacturing establishments and not at all in dwelling-house sewage.

The writer is indebted to Mr. James A. Darling, superintendent of sewer construction of the street department of Newton, for much of the cost data and information as to breakages, etc., in this article.

HENRY A. VARNEY.* — Brookline has tried many different materials for sewer pipe joints, but as yet has found nothing that is entirely satisfactory.

For many years Roslindale cement mortar was used, and no great care taken in forming the joint, which resulted in much trouble from tree roots, and a large amount of leakage in wet ground.

Later on, Portland cement was substituted for the natural cement, and the pipe centered with a jute gasket. But with every precaution we were able to enforce, such as the use of rubber gloves in applying the mortar and deferring the heavy backfilling until the cement had thoroughly set, the results were not at all satisfactory. In one case where there was a large amount of ground water, we constructed wooden boxes to fit the lower half of the pipe and long enough to extend each side of the bell. These were set to the proper grade, then filled with rich mortar, so there could be no question but that each joint was thoroughly bedded and protected. With all these precautions, there was considerable leakage. In another instance we encased the entire pipe in 6 in. of concrete, but with no better results.

We then tried the sulphur and sand joint similar to that used in Newton. By this method we greatly reduced the amount of leakage, but we were apprehensive that such a rigid joint as this material makes from the moment it is poured would result in cracks in the bells or the pipe itself, for it is difficult to bed several lengths of pipe so as to prevent all possibility of movement when the backfilling and puddling is completed.

We next experimented with various bituminous compounds, and in 1909 used a mixture of asphalt and sand in laying a 30-in. sewer. This gave so much better results than anything we had

* Town Engineer, Brookline, Mass.

TABLE I.

DATA RELATING TO SEWER PIPE JOINTS.

City or Town.	Material Used.	How Long Used.	Why Is This Material Used.	Work Done by City or Contract.	Other Material Us
Boston	Cement mortar	30 yrs.	No better for all purposes	Both	None
Brockton	Portland cement	25 yrs.	Think it the best	City	G-K compoun
Brookline	Asphaltic compound	10 yrs.	Gives best results	Contract	Cement, Sulphur and sa G-K compoun
Cambridge	Cement mortar	28 yrs.	Considered practical	City	Bituminous filler
Concord, N. H.	Cement mortar	25 yrs.	Makes Effective joint	City	Roman cemei
Haverhill	Cement mortar	Many yrs.	To prevent entrance ground water and tree roots	City	None
Lawrence	Cement mortar	Always		City	None
Lynn	Cement mortar	40 yrs.	Most convenient	City	None
Malden	Cement mortar	26 yrs.	Considered best	Both	G-K compou
Melrose	Cement and G-K compound	G-K past 2 yrs.	On account of wet trenches and tree roots	City	
New Bedford	Cement mortar	Many yrs.	For convenience and economy	City	G-K compou
Newton	Sulphur and sand	11 yrs.	Permanent water-tight and resistant to roots	Both	Cement mort and bitumino compound
Pawtucket	Cement mortar	20 yrs.	Most satisfactory	Both	None
Worcester	Cement mortar cloth-wrapped	20 yrs.	Because it has given good results	City	None
Metcalf & Eddy	G-K compound	5 yrs.	A poured joint considered best	Contract	Sulphur and sa

TABLE 1. — *Continued.*

DATA RELATING TO SEWER PIPE JOINTS.

...e you ...Trouble ...n Tree ...ots?	Does Present Type Prevent Roots?	Does it Make Water-Tight Joints?	What Material Used in House Connections.	Remarks.
Yes	No	No, except with extreme care	Cement mortar	Experiment under way with special material.
Yes	No	Yes	Portland cement	Iron pipe with lead joints used where roots give trouble.
Yes	Yes	When carefully used	No regulations	House connections laid by private contractors.
ome	Yes, if carefully made	Yes	Cement mortar	
Yes	Yes	Yes, when well made	Cement mortar	
Yes	Yes, if done properly	Yes	Cement mortar	
Yes	No	No		Combined system of drainage.
Yes	No	Nearly	Cement mortar	Iron pipe with lead joint used where tree roots give trouble.
Yes	Yes, if made properly	Yes, if made properly	Cement mortar	
Yes	Yes	Yes	Any	Troubled with tree roots in house connections and some main sewers.
No		No	Cement mortar	
No	Yes	Yes	Sulphur and sand	
y little	Not entirely	Not entirely	Cement mortar	Quality of work depends upon inspectors.
No	Yes	Fairly	Cement mortar	
No	Yes	Fairly so	G-K compound	

previously tried that we continued its use, and up to the present time have found nothing that is more satisfactory, considering the ease of manipulation, cost, etc. The method of making a joint with this material is similar to that used for lead joints, except that the material does not have to be calked. It also required very little heat to bring the compound to the proper consistency, a small wood fire being all that is necessary. We take the precaution to fill the angle between the bell and the barrel of the adjacent pipe with cement mortar, but do not think this is absolutely necessary, especially in the smaller sizes of pipe.

We have recently inspected some of the first work done with this material and have found the joints in perfect condition, and could see no change in the consistency of the compound itself.

In Table 1 are tabulated the results of an inquiry as to methods used in other communities.

L. M. Hastings.* — In Cambridge, experience has shown that the larger-sized sewer pipes are not adapted to the conditions as to foundation, load, etc., which obtain there, without danger of fracture of the pipe. For some years now, it has been the practice to confine the use of vitrified sewer pipe to sizes of fifteen inches in diameter and under. Diameters larger than fifteen inches are made of concrete, brick, or a combination of the two materials. Sometimes the invert of the sewer is made by casting the same in the trench in prepared forms. This makes an excellent base without joints and is sometimes quite inexpensive in construction, as sand and gravel found in the trench, if suitable, can be used.

One disadvantage of this type is the time required to allow the concrete to set before the forms are removed and the arch placed, thus delaying the trench backfill. In some recent work with a heavy cut, a pre-cast invert was used with very satisfactory results. A section of two sizes of this sewer is shown in Fig. 1. The inverts are cast in lengths of two feet, and the arch pieces in lengths of three feet. The end joints are made up by plastering the ends with rich mortar placing a gasket

* City Engineer, Cambridge, Mass.

of hemp near the outer edge and squeezing them together by sliding them on the plank mud sills which have been carefully set at the proper sub-grade. All joints are pointed inside and out after the pieces have been set. Very little time is lost in constructing the sewer by this plan, as the trenching work can be carried on almost continuously. The concrete sections are made by the regular sewer men at the yard, so that they cost but little more than the cost of stock and transportation.

Our practice in making up the joints in 8, 10, 12 and 15 in. pipes, is to use Portland cement mortar and use the fingers and trowel in filling the joint and forming the collar outside. Warren

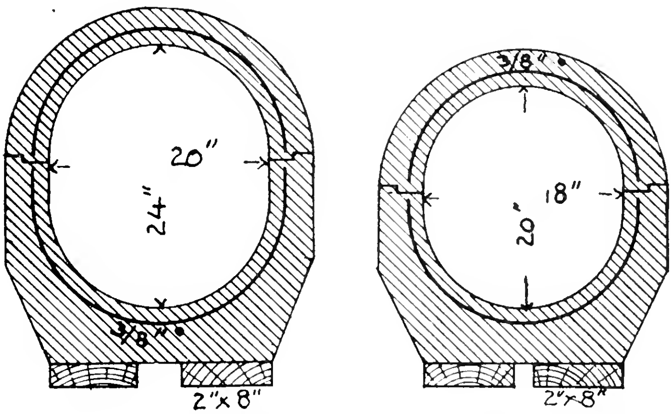

FIG. I. CITY OF CAMBRIDGE. CONCRETE SEWER SECTIONS

Bros.' bituminous joint compound was used several years ago, but the city men, accustomed to the use of cement, preferred that, and so the superintendent of sewers thought that there was not advantage enough in the Warren Bros.' compound to warrant a change. Such trouble as we have has been caused almost invariably by careless work in making up joints of the main city sewer, or the connecting house drains. It must be remembered that a prolific source of stoppages, roots and leakage in public sewers is broken and defective house connections, which no amount of care or expense in the city construction will eliminate.

Personally, I believe that the cement joint — unless an expert is employed on the work — is likely to give as good results as any. Its simplicity, ease of handling the material and detecting imperfections, and its common use by masons and other workmen, are strong points in its favor. I believe, however, that the poured grout is the best way in which to use it and get a full joint. With the poured joint, liability of having an imperfect joint on the bottom side of the pipe is reduced to a minimum and must be the result of gross carelessness, as the bottom part should be best part of the joint by this method. The pipes are first lined up and centered, and a strand of oakum lightly driven into the joint, and then the joint is poured. Various devices have been suggested for holding the cement grout in place when poured. A very simple and inexpensive one is a sort of band or collar made of paper fabric about two and one half inches wide, one edge of which is attached to the bell of one pipe and the other edge is attached to the body of the next pipe, by cords passing around the pipe and firmly binding the collar to it. The grout is then poured into the joint space through a hole in the collar until it is entirely full. The collar can be left in place, as the expense of the collar is very small.

Bertram Brewer.* — The Waltham sewer system consists uniformly of sanitary sewers. It is 46.5 miles in extent, with 44.7 miles of vitrified clay pipe. This pipe is of all sizes up to twenty-four inches in diameter. Seventy per cent. of the sewers was laid by contract before Portland cement was known, and natural cement mortar was used for jointing in the proportion of one part of cement to two of sand. A jute gasket was calked into the joint before applying the mortar. Underdrains were constructed to a great extent in wet trenches, and care was exercised to secure water-tight sewers. Considering the hurried manner in which the work was prosecuted and the lack of skill of both the pipe layers and inspectors, the results were very good. Measurements of the Waltham sewerage, taken by the Metropolitan Sewerage Board, show that Waltham sewers are about as free from ground water as those of any other municipality in the district. As soon as the original contract

* City Engineer and Superintendent of Water Works and Sewers, Waltham, Mass.

was completed, the city laid many of the connections by day work. These also were hurriedly laid and not enough care was taken in the jointing.

Two difficulties with this early construction soon developed. First, the jute gasket has proved more of a nuisance than a help, because in a great many cases it was not properly calked into place. After the contract was completed there was hardly a section of sewer which did not show on examination either a string or a loop of jute protruding into it. The second difficulty had to do with tree roots. Probably no one could tell a bigger story of the length and size of tree roots taken from the sewers than the Waltham authorities.

Most accounts of the improvements in sewer jointing begin with the introduction of Portland cement. For general use, with the ordinary bell and socket pipe and in dry work, nothing better than Portland cement mortar has been discovered. A rich mortar joint, one of cement to one of sand, uniformly pressed into the space between bell and socket and wound with cloth, has been found to keep out tree roots, over and over again. It accommodates itself to the slight movement which every pipe experiences before backfilling is complete. Moreover, if given a chance to set up without being seriously disturbed, such a joint is nearly water-tight.

The discovery of the use of the cloth wrapping is one of the greatest improvements in sewer jointing yet introduced. It gives the skilled pipe layer an excellent opportunity to pull and push and smooth the mortar into place and protects the mortar during backfilling.

When used with a large follower, large enough to fully clean the inside of the pipe, the gasket is not necessary, is not as permanent as the cement, and has been abandoned.

For wet work both the sulphur-sand and the asphaltic composition joint have been thoroughly tried. The asphaltic joint has been adopted.

The first sulphur-sand joints were used in 1907, in a connection where a water and drain pipe were laid in the same trench. The water pipe was laid after the sewer, and, as a result of the jarring the sewer received, several pipes were broken, all

of them on the line back of the bell. This joint was, however, used in several wet trenches later in that season. There is no difficulty in securing a sand in Waltham fine enough for the sulphur joint, and the men soon learned to heat the mixture properly. After that year, however, it was abandoned. The experience cited indicated that the joint was too rigid. The writer has never yet seen a sewer where there was not some movement of the pipes after they were laid. It might be only very slight and, with care, it need be only very slight, but in the case mentioned, where there was no appreciable change and the pipe was subjected to very little stress, failure resulted. Further experience goes to show that the decision to abandon the use of the sulphur-sand joint was a sound one. In 1917 a 300-ft. line of 5-in. pipe, laid ten years before, where the joints were of the type now under consideration, was taken up and relaid at a lower level. When excavated, this sewer to all appearances was at a true grade and perfectly sound, but when jarred out of line, over a third of the pipes were found to be completely fractured at the back of the bell. The annular cracks were so fine that they could not be seen until the sewer was moved.

The asphaltic compositions since 1907 have been invariably used in wet places. Thus far no failures have been discovered. The Warren Bros.' pipe jointing compound has usually been employed. A jute gasket is calked into place and the compound poured into the joint in the usual manner. In shallow trenches every third joint, and in deep trenches every other joint, is made up in the trench; the rest are poured on the bank. With the asphaltic, as well as with the sulphur-sand, joints only deep and wide socket pipe was used. Both the inside of the bell and the end of the spigot should be scored by the manufacturer, else the pipes are liable to pull apart. Care must be taken to see that the compound does not break through the gasket and protrude into the sewer.

The asphaltic joint has been used in Waltham on domestic sewers only, and the danger of hot water melting the compound has never arisen. Its great advantage is that it has considerable flexibility and can be used in a wet trench and without an under-drain, unless there is more ground water than can be taken care

of with a trench pump operated with a gasoline engine. A covering of Portland cement has sometimes been added to keep the compound in place, in case it should later be subjected to unusual heat; but, if the cement is to be made at all effective, this necessitates the introduction of expensive unwatering operations, which are not required with the composition alone. The cement covering was, therefore, used on the earlier jobs only.

A few years ago the department laid about 120 ft. of 10-in. pipe in a shallow, wet trench alongside of a brook. The ends were plugged and the sewer was left over night without backfilling. During the night the water rose considerably, and in the morning the whole 120 ft. of sewer was afloat. This experience increased our faith in the asphaltic jointing compound. When trying it out at the sewer yard, four years ago, two pipes joined together at that time were left there for observation. They have been exposed to all kinds of weather, kicked about and pretty well abused. The joint in these pipes is perfect to-day, and they are in as good alignment as they were the day it was poured.

Of course the human element in the art of joint making is the most important one, after all. The writer would prefer a skilled and conscientious workman above everything else. If, in addition, one can be found who will also make an intelligent use of the latest discoveries in the art, the engineer is indeed fortunate. Engineers should also bear in mind that many vitrified clay pipes are somewhat porous thoughout, and it is, therefore, very doubtful whether all the leakage in the sewer comes altogether from the joints.

In conclusion we would suggest that for deep trenching we want, in common with the contractors, a kind of joint which will allow immediate backfilling over it. The saving in cost, effected by throwing the bottom layer of earth ahead of the pipe just laid, on top of it as backfilling, is of great importance to those who pay the bills.

David A. Hartwell.* — During the last seven years in Fitchburg sewer pipe joints in sanitary sewers have been of two kinds, depending largely upon the trench conditions. Where

* Formerly Chief Engineer, Sewage Disposal Commission, Fitchburg, Mass.

the trench was comparatively dry with no probability that the water plane would for any length of time, if ever, be above the pipe, a cement joint was used. These joints consisted of a ring of jute calked in to assure a uniform annular space. The jute was soaked in a thin mixture of cement and water. The balance of the joint was filled with a one-to-one mixture of cement and sand pressed in by the hand and trowel and the outside smoothed off on a bevel. Portland cement was always used, and care taken to assure as tight a joint as possible, not on account of ground water but to avoid trouble from roots.

Where the water plane was normally above the pipe, and where there was water in the trench, a poured joint of what is commercially known as G-K compound was used almost wholly. Other similar material was used to some extent, but G-K seemed to be more satisfactory. A round commercial gasket was used. The joint was first calked with dry jute, using no more than enough to assure a uniform annular space and to prevent the jointing material from running into the pipe. Joints were poured when the water stood as high as 6 to 8 in. above the invert, and no difficulty was found in making the joints tight enough to prevent any objectionable leakage, The G-K was melted in a gasoline kettle owing to the better control of the heat than when wood is used. It was found advisable to keep the same workman on the kettle as there was less liability of injury to the material when a man has had some practical experience.

All sewer pipe used in recent years has been in 3-ft. lengths when obtainable, and also has had deep and wide sockets. Standard pipe is more economical than deep and wide socket pipe, as it takes less material to fill the joint. But with allowable variation in the diameter of the pipe the annular space with standard pipe was so small that it was decided to use deep and wide socket. It was considered that the cost of the additional amount of jute and compound or cement was more than offset by the better joint secured.

In the construction of drains or storm sewers, cement joints only were used, as with these sewers it was not expected that there would be any trouble from roots, and the elimination

of all ground-water leakage was not considered important.

The cost of joints made with G-K compound was found to be about one third more than cement joints, and owing to this additional cost it was decided to use this material only where there was water in the trench.

Frank R. A. Marston.* — Prior to 1907, Metcalf and Eddy specified cement mortar joints for vitrified pipe in separate sewers as well as storm drains, but since that year some form of poured joint has been generally used in their practice, where it was essential to keep out ground water.

The cement mortar joints are now specified as follows:

> The joints shall be as nearly water-tight as possible, and shall be made with a gasket of hemp or jute and cement mortar composed of one part of sand and one part of Portland cement. The gasket shall be soaked in a satisfactory mixture of neat Portland cement and water and then inserted between the bell and spigot and carefully calked into place with suitable calking tools. The gasket shall be in one continuous piece for each joint and of such thickness as will bring the pipe to the required relative position. The remainder of the joint shall be filled with cement mortar applied with the hands, protected with rubber mittens, well pressed and calked into place, after which the joint shall be beveled off with mortar for a distance of two inches from the outer edge of the bell. The joint shall be wrapped in unbleached cotton cloth, securely tied to prevent the mortar from slipping or being otherwise injured. No surplus mortar or other foreign substance shall project into the pipes from the joints, and if necessary, they shall be properly cleaned with a suitable scraper or by other means before the mortar becomes hardened.

It has been found difficult on contract work, to get sufficiently water-tight joints in this manner, although the use of cheesecloth for wrapping the joints was of value in preventing the bottom of the joint from falling off.

A mixture of sulphur and sand — using equal parts by volume of flour of sulphur and very fine sand — was used on several contracts. Unless the sand is very fine and practically free from clay the resulting joint is apt to shrink on cooling, causing objectionable cracks. Further, the sand, if too coarse,

* Designing Engineer, with Metcalf & Eddy, 14 Beacon Street, Boston, Mass.

tends to settle out of the mixture, causing trouble in pouring and shrinkage of the joint. Some very successful work, however, has been done with this material. It appears to require more care in heating than some other mixtures. The chief difficulty has been to get a satisfactory mixture, due almost entirely to the size and quality of the sand. On contract work, this is a disadvantage. The joint, also, is absolutely rigid, as is the case with cement mortar.

When using sulphur-sand joints, the joint, after being poured and while warm, was coated with hot tar as a further precaution against leakage.

During the last few years, a number of compounds for jointing vitrified pipe have been placed on the market. Since 1913, Metcalf & Eddy have used that known as G-K compound, now made by the Atlas Company, of Lincoln, N. J. This material, said to be made largely of vulcanized linseed oil and clay, resembles vulcanized rubber or coal tar in appearance. It is delivered to the work as a solid, in barrels. It is easily melted by heating in an iron kettle over a fire, preferably using gasoline or kerosene, so that the heat may be controlled.

Specifications for making this form of joint as well as sulphur-sand, are as follows:

Where plastic joints are specified, the pipe shall be laid as previously specified, and the joints shall be thoroughly calked with a gasket of hemp or jute in one continuous piece, and of such thickness as will bring the pipes to the required relative position. The gaskets shall be calked dry and shall form a water-tight joint. The plastic compound to be used in jointing the pipes shall be that known as —— compound, manufactured by ——, or other plastic jointing material satisfactory to the engineer. The compound shall be heated in a gasoline or other suitable furnace, to a temperature slightly above that at which it will pour rapidly and smoothly; at which it shall be kept until used. After the pipe joint has been calked, the melted compound shall be poured into the joints by the use of a joint runner or gasket, in a similar manner as lead joints are poured. In case the pipe joint is not completely filled, that part of the joint shall be poured again with hot material, to form a complete water-tight joint. Wherever permitted, sections composed of two or three pipes may be jointed at the side of the trench, provided the pipes are set in a suitable wooden cradle to ensure true align-

ment. In lowering sections, so made, into the trench, a piece of timber shall be run through the pipes in order to support their weight and prevent the joints or bells from being broken.

Asphalt has not been used, or any of the bituminous compounds, to any extent, because of the danger of hot water or steam melting out the joint due to the low melting points of most of these materials. With a sufficiently high melting point, this objection would be covered.

Some trouble has been experienced during cold weather with G-K compound, due to its failure to stick to the pipes, especially in the smaller sizes where the inside of the bell is glazed and there are no scorings.

From tests made both in the laboratory and on contract and day labor work, the results obtained with G-K compound have been satisfactory.

The cost of a jointing material and labor will be from 50 per cent. to 100 per cent. more with a poured joint than with cement, judging by average prices received. Part of this excess cost is doubtless due to the unfamiliarity of contractors in general with poured joints for vitrified pipe.

Sheet metal forms and gaskets for pouring cement grout joints have recently been placed on the market by Mr. L. A. Weston, of Adams, Mass. The device is shown in the accompanying cuts, Figs. 2 and 3. The writer understands that the price of the gasket is ten cents for a 10-in. pipe and ten cents for the form, thus making a cost of twenty cents per joint for the form and gasket. The gasket, of course, is left in place, and it would appear probable that the form, also, would be left in place, as a rule. The gasket is made to fit over the spigot end of the pipe, being tightened with a screw driver. The notches in the edge are pliable so that the gasket adjusts itself to the inequalities in the pipe hub. No jute is required.

The form provides for pouring the lower half of the joint, the remainder being filled by hand with cement mortar. The form is held in place by wires.

In order to offset the expense of the form and gasket, a material saving in labor cost must be made in addition to the saving in cost of materials over poured joints using other materials than cement.

It seems to the writer that there is a good deal of merit in Mr. Hastings' suggestion to pour the entire joint with thick cement grout, using a paper or other cheap form which can be left in place and make it unnecessary to keep the trench open more than a few hours at the most.

The writer believes that a poured joint is the most desirable

form of joint yet devised where it is essential to prevent the entrance of roots and ground water. Good results have been obtained with a sulphur-sand mixture, with bituminous compounds such as those manufactured by Warren Bros., Boston, the Pacific Flush Tank Company, New York, the Standard Paint Company, Boston, and others; and with G-K compound,

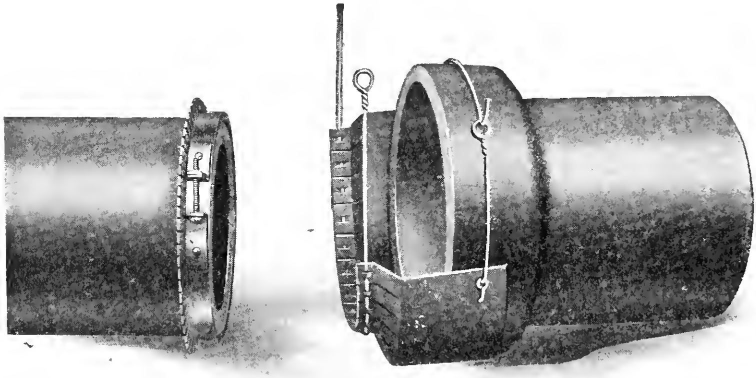

FIG. 2. WESTON GASKET AND FORM.

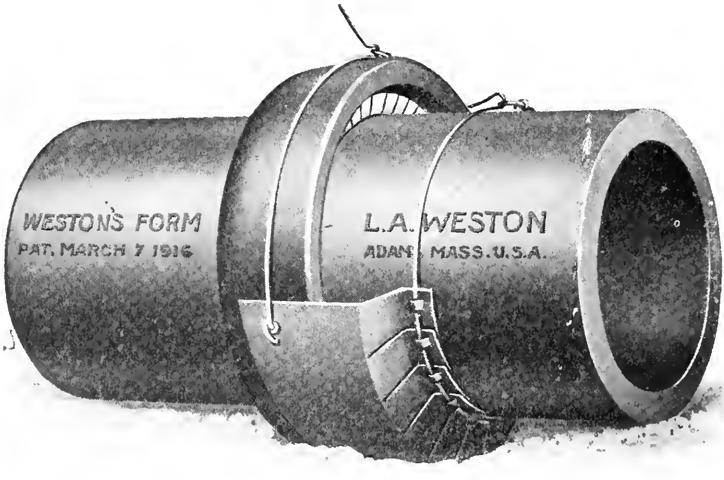

FIG. 3. WESTON GASKET AND FORM IN POSITION FOR POURING.

made by the Atlas Company, Lincoln, N. J. On contract work, these commercial compounds may have some advantages from the contractor's viewpoint.

On account of the imperfections in the so-called "standard" socket sewer pipe it is almost necessary to use "deep and wide" socket pipe if poured joints are to be adopted. Otherwise there is liable to be insufficient space for the flow of the jointing material.

George A. Carpenter.* — We have had no experience with the poured joint in Pawtucket, for we have adhered to the old-fashioned mortar joint. In recent years we have required the mortar to be placed by hands covered with rubber mittens rather than by the trowel, and we have recently used a strip of cloth about nine inches wide to cover the joint after it is made. This strip of cloth is laid on the ground, partly under the bell of the pipe last laid, and mortar is spread on the cloth and in the bottom of the bell with a trowel. A gasket is then placed around the spigot of the pipe to be laid, and it is inserted in the bell of the other pipe, care being taken not to disturb the mortar spread on the bottom of this bell. The pipe is pushed home, brought to proper line and grade on the bell end and the gasket is calked. The joint is then filled with Portland cement mortar proportioned one to one, especial care being taken to see that this mortar is crowded into the joint on the under side of the pipe. The mortar joint is beveled with a trowel, or by the hand, and then the two ends of the strip of cloth are brought up around the joint and tied together over the top of the bell. This serves as a protection to the green mortar, holding it tightly up against the joint and preventing its disturbance as the backfilling progresses.

After all is said, however, the integrity of the sewer joint depends, in large measure, upon the inspector. If he is not on the job all the time, watching the joints as they are made, the workmen will get careless. The joints will be perfect on the top where they are readily inspected, but on the bottom, where there is the greatest necessity that they should be tight, they are apt to be neglected.

* City Engineer, Pawtucket, R. I.

Vol. V MARCH, 1918 No. 3

BOSTON SOCIETY OF CIVIL ENGINEERS
FOUNDED 1848

PROCEEDINGS

SEVENTIETH ANNUAL MEETING.

THE annual meeting of the Boston Society of Civil Engineers will be held at the Boston City Club, Ashburton Place, Boston, on

WEDNESDAY, MARCH 20, 1918.

The annual meeting this year will consist, as usual, of three principal features, the order, however, being slightly changed. The annual dinner will be the first feature, followed by the business meeting and closing with the smoker.

PROGRAM.

Annual Dinner. — The thirty-sixth annual dinner will be served at 1.30 o'clock P.M., in the main banquet hall or auditorium on the fourth floor of the Clubhouse.

At three o'clock, Mr. Robert Ridgway, engineer of Subway Construction, will give an illustrated talk on "The New York Subways."

Those who find it impossible to attend the dinner are strongly urged to be present, at least, for this portion of the entertainment.

Business Meeting. — The annual meeting required by the constitution will be called to order at 5 o'clock, in one of the smaller dining-rooms on the eighth floor of the Clubhouse.

Business.—Announcement of the election of new members.

To receive the annual reports of the Board of Government, of the Treasurer, and of the Secretary.

To receive the annual reports of the several special committees.

To reappoint the several special committees.

Announcement of the result of letter-ballot for officers for the ensuing year.

Address of the retiring President.

Smoker. — The usual informal smoker will be held in the evening, in the main banquet hall, on the fourth floor of the Clubhouse, beginning at 6.30 o'clock.

S. E. TINKHAM, *Secretary.*

PAPERS IN THIS NUMBER.

"The Mesabi Iron Range." Frank B. Walker.

"The Hydraulic Laboratory of the Massachusetts Institute of Technology." George Edmund Russell.

"Effect of Heating Concrete Materials in the Mixer." H. E. Sawtell.

"Discussion of the Foundations of the New Buildings of Massachusetts Institute of Technology." J. R. Worcester.

Memoirs of Deceased Members.

CURRENT DISCUSSION.

Paper.	Author.	Published.	Discussion Closes.
"Economy in the Design of Concrete Buildings."	C. W. Mayers.	Feb.	Apr. 10.

Contributors are hereby notified that proof will not be submitted to them for examination unless requested before the 10th of the month preceding the month of publication.

MINUTES OF MEETINGS.

BOSTON, January 11, 1918. — A special meeting of the Boston Society of Civil Engineers was held this evening in Chipman Hall, Tremont Temple, and was called to order by the President,

George C. Whipple, at 8 o'clock. There were present 125 members and guests, a large proportion of the latter being ladies. An informal reception in the Society rooms preceded the meeting.

Mr. John R. Freeman, a past president of the Society, gave a most interesting talk on "The Experiences of an Engineer in the Far East."

Mr. Freeman illustrated his talk with a large number of very beautifully colored slides, made in Japan from photographs gathered by him on his trip, many of which were taken by himself.

Adjourned.

S. E. TINKHAM, *Secretary.*

BOSTON, February 20, 1918. — A regular meeting of the Boston Society of Civil Engineers was held this evening at Chipman Hall, Tremont Temple, and was called to order by the President, George C. Whipple, at 8 o'clock.

There were 140 members and visitors present.

By vote the reading of the record of the last meeting was dispensed with and it was approved as printed in the February JOURNAL.

The President reported for the Board of Government that it had elected to membership, in the grade of member, Messrs. John McNeil Emerson, Louis John Killion, Fred Eugene Sauer, Jr., and Harry Lancaster Strand.

The Secretary submitted for Mr. Charles T. Main, the committee appointed for the purpose, a memoir of Henry A. Herrick. By vote, the memoir was accepted and ordered printed in the JOURNAL.

The President announced the death of Charles W. Gay, a member of the Society, which occurred at Lynn, Mass., on February 1, 1918, and by vote he was requested to appoint a committee to prepare a memoir. He has named, as this committee, Messrs. W. L. Vennard and Frank B. Rowell.

A communication was read from the Municipal Section of the Providence Engineering Society, extending an invitation to the members of this Society to be present at a meeting to be

held in Providence on April 24, 1918, at which Mr. Frank E. Winsor will speak on " The Development of the New Providence Water Supply to Date."

By vote the thanks of the Society were extended to the Providence Engineering Society for its courteous invitation, and the Secretary was directed to bring the invitation to the attention of the members of the Society.

A letter was read from Mr. J. R. Worcester, addressed to the Society's Committee on Legislative Affairs, calling attention to House Bill No. 1220, which deals with the engineering sections of the Boston Building Laws and is an attempt to bring them up to date.

On motion of Mr. Sherman, the thanks of the Society were voted to the Aberthaw Construction Company for courtesies extended to members who took part in the excursion, this afternoon, to the Squantum Destroyer Plant, and for its generosity in providing transportation to and from the plant.

The following vote, passed at the last meeting of the Society, was again passed by a unanimous vote, as required by the By-Laws:

"*Voted*, that a sum not exceeding one hundred and twenty-five dollars be transferred from the income of the Permanent Fund to the Current Fund, to cover the amount of unpaid dues for the present year of members who are in the war service of the country, and which have been remitted by the Board of Government under authority of the By-Laws."

The President then introduced Lieut. Robert B. Street, chaplain of the Twenty-fifth Regiment of Engineers, U.S.N.A., which is now stationed at Camp Devens but is expected to be ordered to France at once. Lieutenant Street made an earnest plea for a contribution to the Chaplain's Fund of this regiment of engineers. He stated that the Government does not provide any funds from which a chaplain can draw to meet the many demands which come to him in his work, and he is forced to raise the money in any way he can. He therefor asked the engineers of Boston to make a contribution to this fund to be used for the welfare and comfort of their brothers who are to go to France.

The President said he would be glad to receive checks from members, to be forwarded to Lieutenant Street. Past-President

Howe said that as there was a large attendance at the meeting, he would suggest that "the hat be passed around." The suggestion was received with favor by the meeting, and as a result a very generous collection was taken up and given to Lieutenant Street.

Mr. Thomas C. Atwood, supervising engineer at the Victory Plant, then gave a most interesting address on "The Submarine Menace and the Squantum Destroyer Plant." The address was illustrated with a large number of lantern slides.

Adjourned.

S. E. TINKHAM, *Secretary*.

WITH THE 101ST ENGINEERS IN FRANCE.

ABSTRACT OF A LETTER JUST RECEIVED.

FRANCE, February 8, 1918.

My dear Mr. Sherman,—I was delighted to get a letter from you a few days ago, and I am taking this, the first opportunity, of answering it. I have had charge of two of the companies of the regiment practically since it landed in France. We have been doing a large amount of construction work under trying conditions. The men have stood up to it well, and have received many commendations from officers high in command.

We have been building what amounts to a small town, with water works, sewerage system, electric lighting, etc., and I have had to be mayor, chief of police, fire department, judge of the court, and all. Have had under me very nearly one thousand men, and it is really some little job to look after their food, clothing, medical attention and all. I have quite a contractor's organization worked up, which would be of considerable value to some contractor if it could but be turned over entire. Osbornville, as the men have facetiously called this addition to the landscape, has grown very fast. But there is other work for us to do shortly, and if I am still able to make my wrist twitch I may be able to tell you something of that other kind of work later. . . .

The regiment got together for a review, the other day, and it certainly made a fine appearance. The band, whose instru-

ments were paid for by the B. S. C. E. fund, is certainly a fine addition and much appreciated by the men. The generosity of the Society made it possible to give these hard-working boys the pleasure of listening to and marching to the martial tunes we love so well. An engineer regiment is not allowed a band, but the help of the Society was such as to give the boys something which would have been greatly missed. Its possibility I believe has had a marked effect on their health and *esprit du corps*. . . .

Very sincerely.

JOHN F. OSBORN,
Captain 101st U. S. Engineers, A. E. F.

APPLICATIONS FOR MEMBERSHIP.

[March 12, 1918.]

THE By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of twenty (20) days from the date given.

BRACKETT, LEROY GILE, Somerville, Mass. (Age 26, b. Biddeford, Me.) Graduate of Boston Y. M. C. A. Evening Polytechnic School, 1913, civil engineering course; has taken several courses with Massachusetts University Extension. From winter of 1911 to June, 1914, rodman, transitman and draftsman with Silverman Engineering Co.; from June, 1914, to date, with N. Y., N. H. & H. R. R. in office of division engineer and in construction

department; is now draftsman in construction department. Elected a junior April 21, 1915, and now desires to be transferred to grade of member. Refers to W. H. Bacon, C. H. Restall, Malcolm Rich and A. S. Tuttle.

SILVERMAN, MAX, Dorchester, Mass. (Age 27, b. Boston, Mass.) Graduate of Tufts College, 1914. From September, 1914, to September, 1916, with Boston Transit Com.; was employed for eight months with Mass. Highway Com.; for nine months to date, draftsman with B. & A. R. R. Elected a junior June 16, 1915, and now desires to be transferred to grade of member. Refers to S. L. Conner, W. W. Davis, P. C. Nash, F. B. Sanborn and S. S. von Loesecke.

STAFFORD, EARL, Somerville, Mass. (Age 32, b. Rockport, Mass.) Graduate of Tufts College, 1908, mechanical engineering course, degree of B.S. From 1908 to 1909, draftsman with Bay State St. Ry. Co.; from 1909 to 1910, draftsman with Boston Bridge Works; from 1910 to 1911, designer on miscellaneous water-power development work with Ambursen Co., of Boston; from 1911 to 1914, designing engineer with George F. Hardy, Boston, and consulting engineer, New York, on paper and pulp mills and hydro-electric developments; from 1914 to 1915, designer with Power Construction Co. on Deerfield River developments in Massachusetts; from 1915 to 1916, designing engineer with Fargo Engrg. Co., Jackson, Mich., on hydro-electric developments; from 1916 to 1917, designing engineer with Utah Copper Co. in Utah and Chino Copper Co. in New Mexico; is now assistant to John F. Vaughan, Cons. Engr., Boston. Refers to H. L. Coburn, E. A. Norwood, Malcolm Rich, H. C. Whitmore and D. M. Wood.

LIST OF MEMBERS.

ADDITIONS.

JONES, PUSEY .... Room 304, North Station, Boston, Mass.

CHANGES IN ADDRESS.

BARNES, T. HOWARD .... 50 Rockland Ave., Yonkers, N. Y.
BOWERS, GEORGE W. .... Care A. Bentley & Sons Co., Jacksonville, Fla.
COFFIN, SAMUEL P. .... 1299 Commonwealth Ave., Allston, Mass.
COGHLAN, JOHN H. .... 5057 Summer St., Philadelphia, Pa.
CURTIS, ALLEN .... Room 8, Union Station, Worcester, Mass.
DEMERRITT, ROBERT E.,
2d Lieut., Coast Artillery Corps, Fort Monroe, Va.
EDDY, H. PRESCOTT, Jr. .... Norfolk Navy Yard, Norfolk, Va.
FARRELL, FRANCIS B. .... 113 Atlantic Ave., Atlantic, Mass.
FLINN, ALFRED D. .... Room 901, 29 West 39th St., New York, N. Y.
FREED, CHARLES .... 12 Greenock St., Dorchester, Mass.
HALL, CHARLES LORING,
Care Isaac Prouty & Co., 133 Main St., Spencer, Mass.

Harty, John J., Jr.,
Capt. Ord. Dept., U.S.R., Springfield Armory, Springfield, Mass.
Huntington, Frederick W. . . . . Belcher St., Holbrook, Mass.
Hurd, Stephen P. . . . . 644 Adams St., E. Milton, Mass.
Lee, Edward G. . . . . Care Southern Power Co., Charlotte, N. C.
Lewis, George W. . . . . . Care Hugh Nawn Contracting Co., Hog Island, Pa.
Perkins, Theodore P. . . . . 352 North Station, Boston, Mass.
Porter, Arthur P. . . . . 15 Glen Rd., Newton Lower Falls, Mass.
Power, William J., Jr . . . . 5 Grant Pl., Waltham, Mass.
Silverman, Max . . . . 26 Fernboro St., Dorchester, Mass.
Smith, Chester W. 160 Middle St., Portsmouth, N. H.
Soutar, George P. . . . . Care U. S. Weather Bureau, Boston, Mass.
Starr, John A. . . . . Box 411, Chatham, Mass.
Stenberg, Thornton R. . . . . 23 Burncoat St., Worcester, Mass.
Strout, Henry E. . . . . Lieut., Camp Fremont, California
Woodbury, Stanley W. . . . . 15 Mall St., Salem, Mass.

DEATH.

Gay, Charles W. . . . . February 1, 1918

EMPLOYMENT BUREAU.

The Board of Government maintains an employment bureau for the Society, to be a medium for securing positions for its members and applicants for membership, and also for furnishing employees to members and others desiring men capable of filling responsible positions.

At the Society rooms two lists are kept on file, one of *positions available* and the other of *men available*, giving in each case detailed information in relation thereto.

Men Available.

418. Age 32. Received technical education at Brown University, class of 1909, civil engineering course. Has had two years' experience on railroad construction and surveying, one year on topographical and city surveying, and four years on construction work. Desires position as engineer on construction work. Salary desired, $45 per week.

419. Age 36. Graduate of Mass. Inst. of Technology, civil engineering course. Experience includes about five years in west on railroad location and canal surveys, six years in office of engineer of structures in Boston, and five months on design of steel and reinforced concrete for steam power houses. Desires position as chief draftsman on structural steel or concrete. Salary desired, $170 per month.

420. Age 50. Graduate of Harvard University, 1890; regular student for three years, Mass. Inst. of Technology; member of Society. Experience as follows: Six years on sewerage, water works, and general municipal engineering; about twenty years as assistant engineer with Boston Elevated Railway Co. on land takings, estimating abutters damages, abolition of five grade crossings, estimates and designs of subways and stations and the complete requipment of stations; investigation of elevated and subway routes and location of stations. Desires position on investigation or construction work. Salary desired, $200 per month.

LIBRARY NOTES.

Recent Additions to the Library.

On Military Engineering and Related Subjects.

Elements of Military Sketching and Map Reading. Capt. John B. Barnes.

U. S. Government Reports.

Annual Report of Chief of Engineers, U. S. Army, for 1917. 3 vols.

Bibliography of Recent Literature on Flotation of Ores, July to December, 1916. D. A. Lyon and others.

Blast-Furnace Breakouts, Explosions, and Slips, and Methods of Prevention. F. H. Willcox.

Cost Accounting for Oil Producers. Clarence G. Smith.

Effects of Grazing upon Western Yellow-Pine Reproduction in National Forests of Arizona and New Mexico. Robert R. Hill.

Firing Bituminous Coals in Large House-Heating Boilers. S. B. Flagg.

Mineral Resources of United States, 1915: Part II, Nonmetals. E. F. Burchard.

Suggestions for Safe Operation of Gasoline Engines in Mines. R. H. Kudlich and Edwin Higgins.

Use of Waterways a War Necessity. Hon. Joseph E. Ransdell.

Waterways and Harbors of United States. S. A. Thompson, Ed.

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Massachusetts. Report of State Board of Health upon Sewerage of City of Salem and Town of Peabody, 1896. Gift of A. F. Brown.

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Chicago, Ill. Report relating to Existing Lake Levels, 1917. George M. Wisner.

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Canada, Department of Interior, Topographical Surveys Branch: Description, Adjustments and Methods of Use of Six-Inch Micrometer Block Survey Reiterating Transit Theodolite, 1912 Pattern. W. H. Herbert.

Canada, Department of Mines: Summary Report of Mines Branch for 1916.

Industrial Arts Index for 1917. Charlotte G. Noyes and Louise D. Teich, Ed.

Power Specialty Co.: Superheated Steam.

Washington's Nine Months at War. Raymond B. Price.

LIBRARY COMMITTEE.

NEW ENGINEERING WORK.

(Under this head a brief description of new engineering work contemplated or under construction will be presented each month. Engineers and contractors are requested to send descriptions of their work to the Secretary, 715 Tremont Temple, Boston, before 1st of each month.)

Commonwealth of Massachusetts. — METROPOLITAN PARK COMMISSION. — *Old Colony Parkway.* — Construction of a temporary bridge across the Neponset River between Boston and

Quincy is in progress; also construction of double siphon for water and gas under new channel.

Boston Transit Commission.—*Dorchester Tunnel.* — Work is progressing on the interior finish of the station at Andrew Sq., and work is in progress on the station for transfer of passengers from the surface cars to the tunnel below.

Boylston Street Subway. — Work has been started on the surface station for the transfer of passengers to and from the Massachusetts Station of the Boylston Street subway.

City of Boston. — Public Works Department, Highway Division, Paving Service. — Work is in progress on the following streets:

Alger St.,	from Dorchester Ave. to N. Y., N. H. & H. R. R.	Moving buildings.
Pontiac St.,	from Tremont St. to Hillside St.	Blasting rock.
Grove St.,	from Centre St. to Washington St.	Taking down trees.

New York, New Haven & Hartford R. R. Co. — *South Boston Cut Improvement.* — Enlargement of South Boston Cut to Boston Freight Terminal, to accommodate four tracks instead of two, and reconstruction of eleven overhead highway bridges, so as to span four tracks instead of two, progressing. Excavation by steam shovel has advanced from westerly end of cut to Silver St. Bridge abutments being constructed at West Sixth St. and West Fifth St. Concrete work retarded owing to extreme cold weather. Permanent pumping plant being constructed at Dorchester Ave.

Vol. V MARCH, 1918 No. 3

BOSTON SOCIETY OF CIVIL ENGINEERS
FOUNDED 1848

PAPERS AND DISCUSSIONS

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THE MESABI IRON RANGE.

By Frank B. Walker,* Member Boston Society of Civil Engineers.

A talk on the mining and hauling of coal would have been appropriate to these heatless days, but probably we are as much interested in the question of an adequate supply of iron and its products as any other.

The Germans say that this is a war of "Blood and Iron," and well they know it. The terrible struggle which Germany is making to retain Alsace-Lorraine is not for the beauty of its mountain scenery, but to retain the very rich potash and iron ore fields of these two beautiful French provinces. More than any other thing, the iron ore of Lorraine has made Germany industrially great. If France had taken Lorraine in 1914, Germany would have been defeated in 1916. Steel men claim that Germany's gigantic drive at Verdun was not so much to take Paris, as it was to close the mailed fist absolutely around the high-grade iron ore district of Briey, which is an extension of the Lorraine ore bodies and contains a much higher grade of ore. Briey is about twenty-five miles east of Verdun.

You may be interested in the steel producing capacity of our country in comparison with Germany. The estimated production in the United States for 1918, is 48 500 000 tons, and a year ago it was 43 000 000 tons. Under stress of war, our steel

* Special Engineer in charge of bridge work, Bay State Street Railway, 245 State Street, Boston, Mass.

men have increased our steel production 13 per cent. Germany has an estimated annual production of steel ingots of 20 000 000

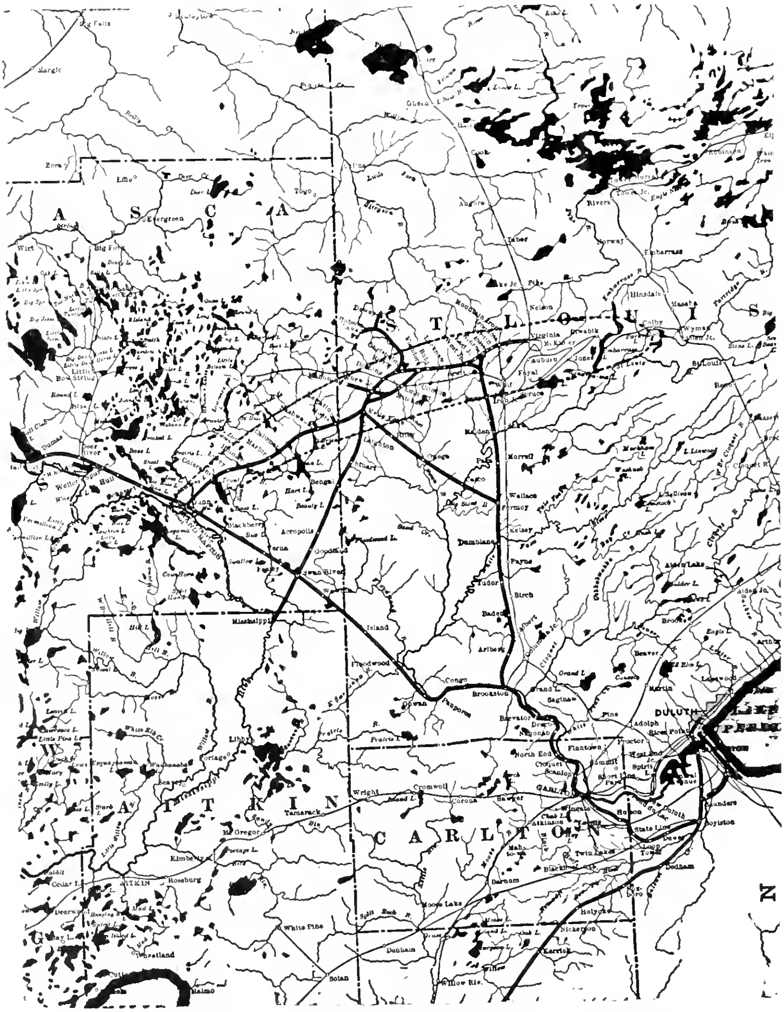

FIG. 1. LOCATION OF THE MESABI IRON RANGE IN MINNESOTA.

tons, against 16 000 000 tons a year ago. England's estimated annual production is 12 000 000 tons, against 8 000 000 tons a

year ago. The estimated world's production for 1918 is 100 000-000 tons of steel, of which we make $48\frac{1}{2}$ per cent.

Now, where do we produce the millions and millions of tons of iron and steel required for munitions, ships, rails, locomotives and thousands of other war purposes? I shall attempt to partially answer this question by giving you a few figures and showing you a few pictures of some of the iron ore mines on the Mesabi Range, Fig. 1, and ore docks in northern Minnesota.

There are three iron ranges or districts in Minnesota. The Vermilion, opened up in 1882, is about fifty miles northeast of the Mesabi, and the Cuyuna, opened up in 1911, is about seventy-five miles southwest of the Mesabi. A diagram, Fig. 2, is shown indicating the relative importance of the two latter ranges. The Duluth-Superior Harbor, at the head of Lake Superior, is about seventy-five miles away from the nearest point of the Mesabi Range. Hibbing is eighty-six miles from Duluth on the Duluth, Mesabi & Northern Ry., and one hundred and twenty miles from Superior on the Great Northern. This harbor, lying in Minnesota and Wisconsin, ships more ore than any other port in the world.

The Mesabi Range is about 75 miles long, and from $\frac{1}{2}$ mile to 3 miles wide. The western end of the range merges into the level of the surrounding country and lies at an elevation of 1 400 ft. above sea level, or 800 ft. above the level of Lake Superior. At the eastern end, near Virginia, the elevation increases to 1 800 ft., or 1 900 ft. above sea level, or about 400 to 500 ft. above the level of the surrounding country. This ridge is called the "Giant Range," "Mesabi" being the original Chippewa Indian name for Giant. There are no mountains in Minnesota. The timbers and soil are characteristic of the lake region. The forests include white and yellow pine, tamarack, spruce, cedar and balsam, with some poplar, birch and maple. However, old choppings, windfalls and many swamps have combined to make the scene a desolate one, and the immense open pits and mountain-high waste dumps, made from mine strippings, do not add to the beauty. Yet all this can be forgotten when it is realized that here is one of Nature's treasure stores, the richest and most productive iron ore district in the world. The

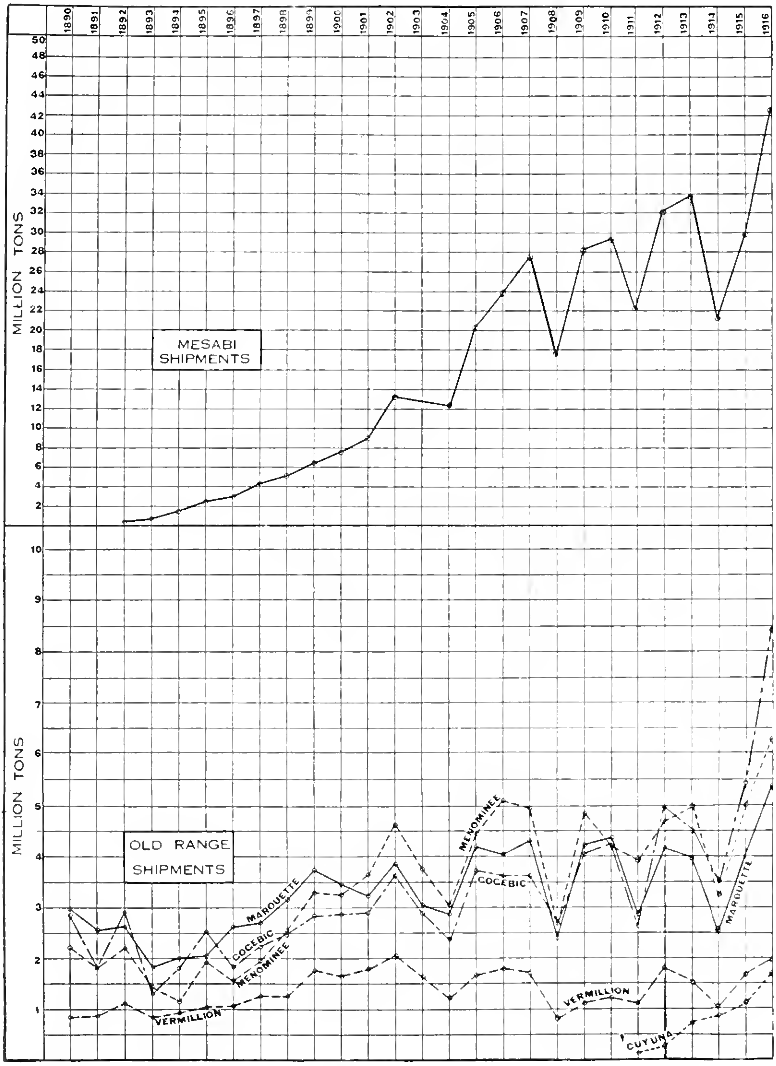

FIG. 2. CHART SHOWING SHIPMENTS OF IRON ORE FROM MESABI RANGE, 1892–1916; OTHER RANGES, 1890–1916.

iron ore found on the Mesabi is called by geologists hematite or ferric hydrate. Following is an analysis of Mahoning ore. Note the high iron content of 62.6 per cent. in this ore.

Analysis of Iron Ore for
Great Northern Iron Ore Prop.
Hibbing, Minn., M., Nov. 2, 1917.

Dried at 100° C.	Per Cent.
Iron	62.64
Phosphorus	.055
Manganese	.47
Silica	4.38
Alumina	2.13
Lime	.18
Magnesia	.15
Sulphur	.011
Loss by Ignition	3.02
Moisture	9.80
Natural Iron	....

Lab. No. 452716
Remarks. Mahoning Mine, No. 3040.
....
....
Analyzed by Lerch Bros.

The ore occurs in isolated bodies or lenses. It lies near the surface, rarely more than 300 ft. deep, is fairly soft and is usually covered with glacial drift, consisting of sand, clay and bowlders. This is called the "over-burden." Mesabi ore is similar in most respects to ore from the so-called older ranges, but differs from these ores in being located so near the surface, and in being much softer. These two characteristics are responsible for its being mined to such a large extent in open pits by steam shovels. Only about 20 per cent. is mined by the underground or shaft method.

The *Iron Trade Review* has kindly permitted me to show you a graphic record of shipments by ranges for the last twenty-seven years, Fig. 2. These and all other figures are in gross tons of

2 240 lbs. I do not want to bore you with dry statistics, but a few figures seem necessary.

In 1916, the Mesabi shipped 42 525 000 tons, and
In 1917, the Mesabi shipped 40 583 000 tons.

The Vermilion and Cuyuna, combined, shipped, in 1916, 3 663 000 tons, and in 1917, 3 953 000 tons. In 1916, the Gogebic, Marquette, Menominee and other smaller ranges shipped 20 469 000 tons, and in 1917, 20 246 000. Total shipments Lake Superior:

1916..........66 million tons,
1917..........64 million tons,

or 85 per cent. of all iron ore mined in the United States.

The falling off of the Mesabi shipments in 1917 was due to the late opening of navigation on Lake Superior. In 1916, boats got started April 22, but in 1917, it was early in June before navigation opened.

It takes about two tons of iron ore to make a ton of steel, so you can readily see what the Mesabi Range is doing to win this war; and, further, do not be alarmed about our running out of ore, as it is estimated that Minnesota has reserves of 1 463 860-000 tons of merchantable ore, of which 90 per cent. is on the Mesabi Range, or enough for thirty-five years at the present rate of mining. The present price of Mesabi Non-Bessemer iron ore, lower lake ports 51½ per cent. iron, is $5.05 per ton.

There are 121 active mines on the Mesabi Range, and 8 shipped over one million tons in 1916. The Hull-Rust made shipments of over 7 million tons in 1916, and shipped in 1916 and 1917 over 14 million tons of ore. This mine is owned by the United States Steel Corporation.

Diamond drilling outfits are always a part of the scenery on the Range. Most exploration work now is carried out by diamond drills. I would not make a guess as to the number of drills operated, but it must run into many hundreds.

Mr. H. H. Eames, in 1866, reported immense bodies of magnetite and hematite ore in this region, and for many years there was more or less exploring. In 1890, the Merritts of

Duluth, who were among the persistent explorers, were rewarded for their faith, as their test pit crew struck ore in the northwest quarter of Town 58, No. Range 18, west, just north of what is now the Mountain Iron Mine, four miles west of Virginia. The discovery of ore at other points rapidly followed.

The Merritts, in 1894, built a line, the Duluth, Mesabi & Northern, from Mountain Iron Mine to Brookston on the Great Northern; and the Great Northern built a small ore dock on the Superior Harbor; and the first ore was shipped over this route in 1894. In 1906 and 1907, it became my duty to remove this dock, then twelve years old, and replace it with what is now Great Northern Ore Dock No. 1, the largest ore dock ever built, up to that date. The Merritts extended their line to Duluth, and through a $600 000 mortgage, their whole property fell into the hands of the Rockefellers, who later turned these properties over to the United States Steel Corporation when that corporation was formed. The Duluth & Iron Range is also owned by the corporation. The Steel Corporation interests are in the name of the Oliver Iron Mining Company, and the Oliver shipped 43 per cent. of all Mesabi ore in 1917, — 47 per cent. in 1916, and 50 per cent. of all ore during the past ten years. The Great Northern Railroad also has very large ore holdings on the range, but these properties are being disposed of to the so-called independents. M. A. Hanna & Co. recently purchased 40 to 50 million tons, and Jones and Laughlin a large tonnage.

I had charge of the engineering work for the Great Northern Railroad on the Mesabi Range and the Lake Terminals for many years, and even though I visited the range several hundred times, I never ceased marveling at the vastness of the operations involved in the stripping, loading and hauling of this ore. Hundreds of locomotives and steam shovels were in operation day and night, with heavy blasting at every meal hour. Just imagine, if you please, loading 7 660 000 tons in less than two hundred working days from one mine. This would make 3 860 000 tons of steel, or enough to lay 20 000 miles of railway with 100-lb. rail, including fastenings; or enough ore to make steel rails to relay the entire Bay State Street Railway in seven days.

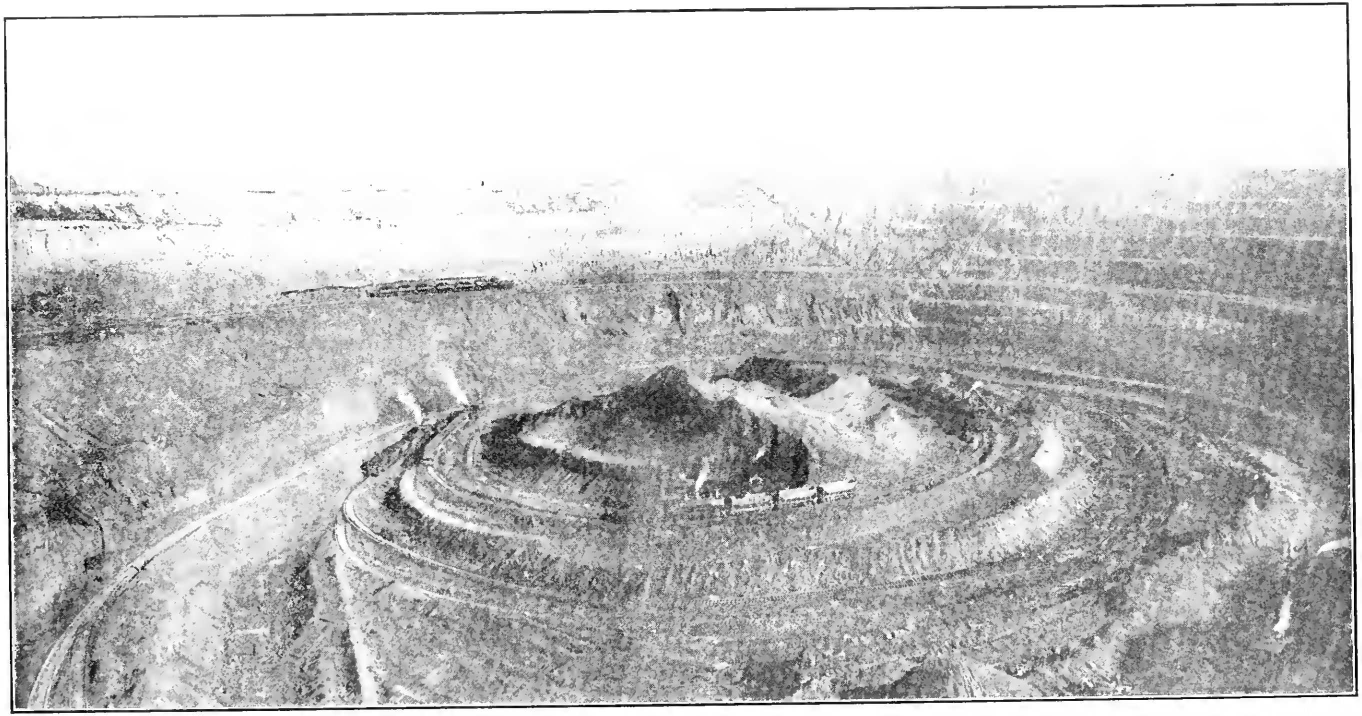

Fig. 3. Shinango Mine — showing Open-Pit Mining Operations.

The railway companies build spurs and yard tracks to serve each mine, and deliver empty ore cars to this yard as many times a day as required; the mine locomotives take the empties into the pits, where they are loaded by steam shovel, 50 tons per car, and then returned to the yard. The Mahoning requires 250 to 300 cars, and the Hull-Rust 700 to 800 cars each twenty-four hours.

Eighty per cent. to ninety per cent. of the ore is mined by stripping off the over-burden with steam shovels and then building standard gage railroad tracks down incline into the mine and loading the ore on to the railroad cars by steam shovel. This over-burden is 20 to 40 ft. thick and can be readily distinguished from the ore in the pictures. Figs. 3, 4 and 5.

One contractor, while I was on the range, stripped one mine of seven million yards of over-burden. John F. Stevens, formerly chief engineer of the Great Northern, and later of the Panama Canal, said that more material was loaded on the Mesabi than was loaded on the canal in the same length of time.

For a long time, it was thought that there was too much sand in the ore on the western end of the range; but several years ago the Wisconsin Steel Company — owned, I think, by the International Harvester Co. — put up a washer at the Hawkins Mine. This was successful, and there are about a dozen plants in operation or under construction. One peculiar result is that washing the ore reduces the moisture content.

Shaft mines work all winter, and put the ore in stock piles. This is shipped out after navigation opens up in the spring. Open pits shut down mining about December 1, and only carry out stripping operations during the winter.

The Grant Mine is owned by the Jones-Laughlin Company, and their engineers conceived the idea of stripping and mining by means of a big clam shell. The experiment cost them a half million dollars and they had stripped 60 000 yards, when the outfit was pronounced a failure by the owners. Others had pronounced its fate earlier in the proceeding.

The capacity of the bucket was 11 yds., and the stock was $1\frac{1}{2}$ in. thick. Every time it broke down — and that was frequently — a car had to be furnished to ship it away for repairs.

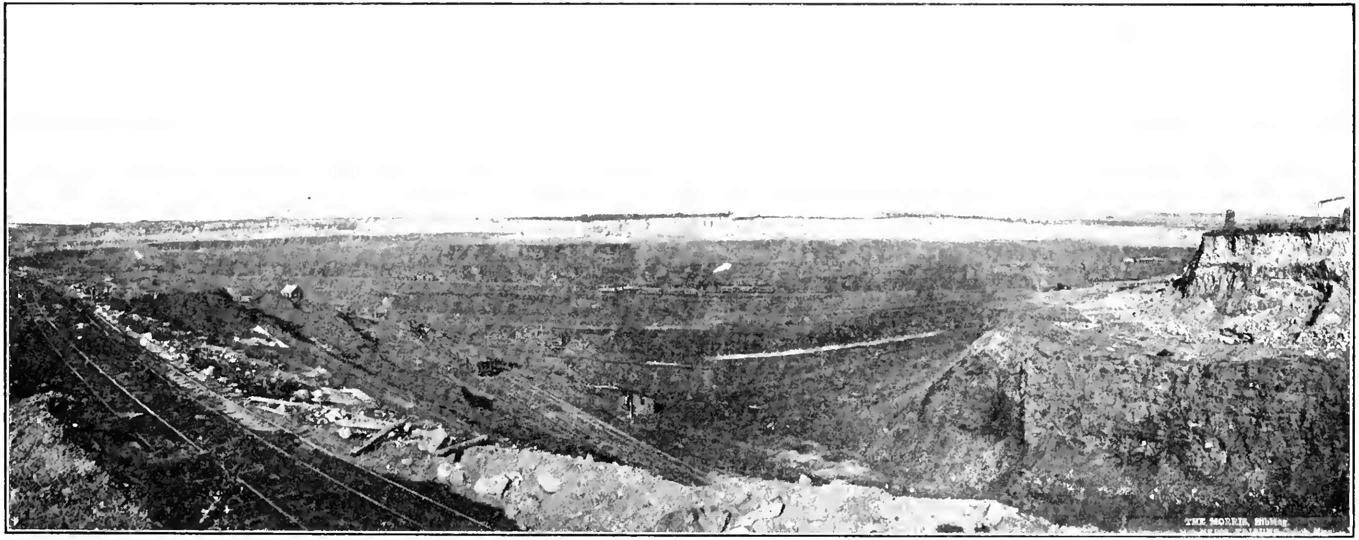

Fig. 4. The Morris Open-Pit Mine near Hibbing, Minn.

This mine, when I last heard, was operated by steam shovels, and they loaded 110 000 tons last year.

The Great Northern has a large ore yard at Superior, near the docks. I had charge of the construction of this yard. The ore trains of 125 50-ton cars are brought into a large receiving yard, and the road engine detached. A large switch engine then pushes these trains of 125 cars over a hump, and the cars run down

Fig. 5. Steam Shovel loading Iron Ore in the Mahoning Mine.

the opposite side by gravity, into classification tracks, of which there are 40. Before the cars leave the mine yard, the ore is sampled, analyses made, and the dock office advised by telephone into just what pocket in the dock each car load is to go. A boat cargo from each mine is accumulated in the dock before shipping. After the ore cars are classified, they are shoved up on to the docks in 18 car "cuts," and dumped through the bottom hoppers. The cars being 24 ft. long, and the ore dock pockets 12 ft., a train would naturally be dumped into every

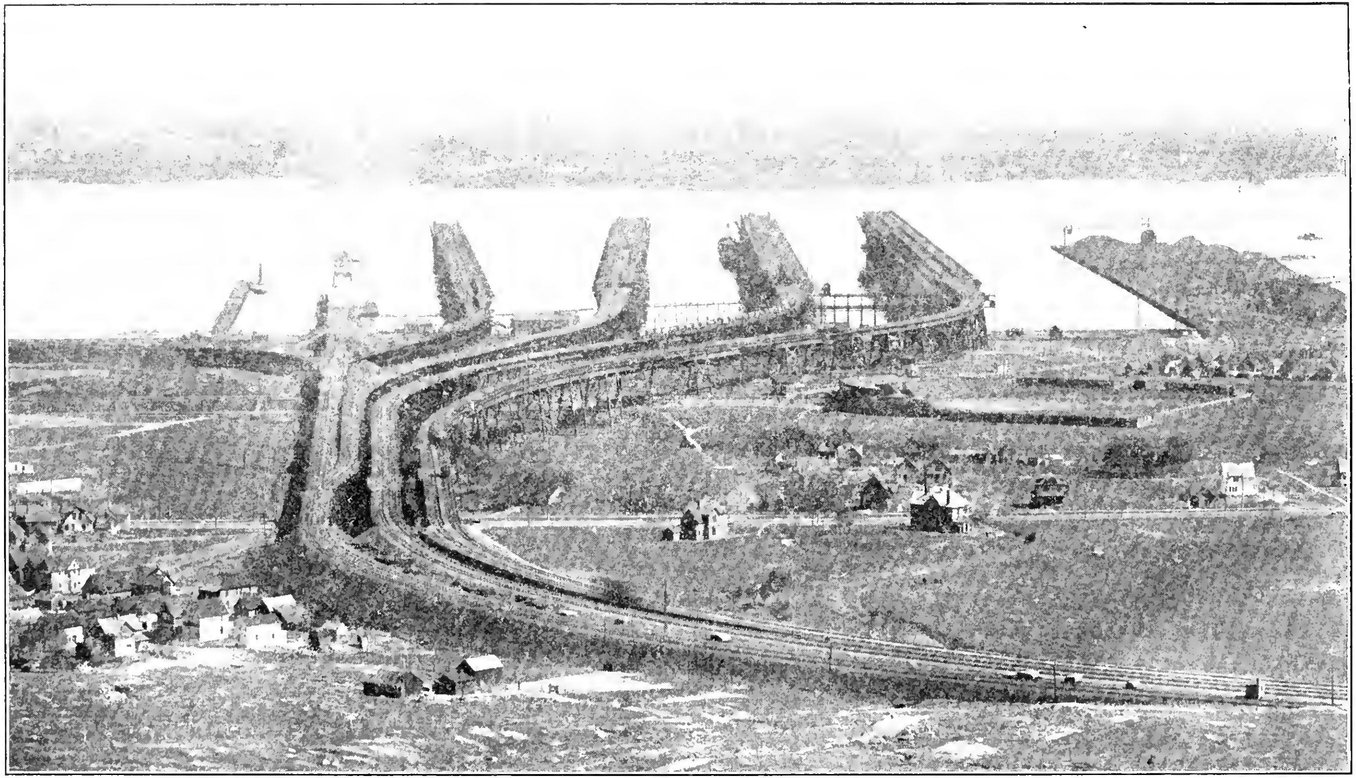

Fig. 6. Ore Docks of the Duluth, Mesabi & Northern Railway, at Duluth, Minn.; Superior, Wis., in the Distance.

other pocket. The alternate pockets would be filled by other trains. On the two humps in the yard, there were four 150-ton track scales, two working and two emergency. Cars are weighed while in motion, and, surprising to say, very accurate results are obtained. All payments are made on basis of these weights, — mining, royalty, rail and water freight and the sale of the ore.

Duluth, Mesabi & Northern has a large yard at Proctor.

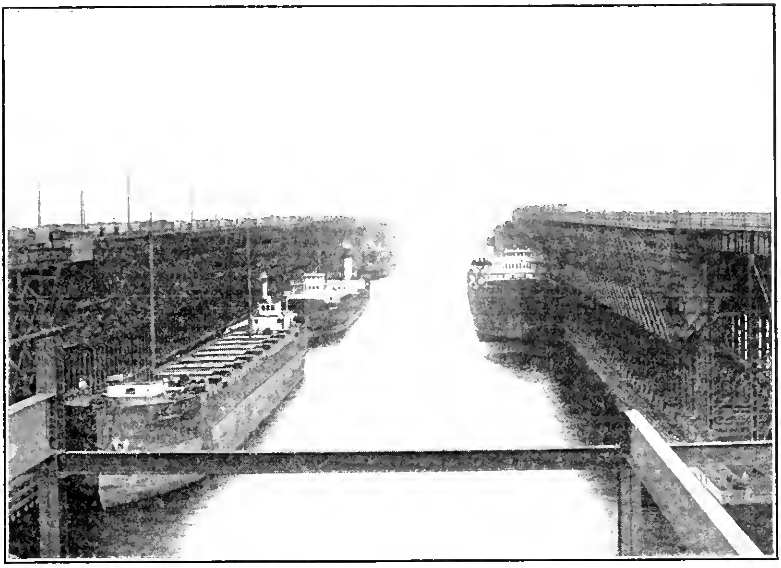

FIG. 7. LOADING IRON ORE AT THE DOCKS IN DULUTH, OF THE DULUTH, MESABI & NORTHERN RAILWAY.

This is on top of the Duluth Hill, about 6 miles from their ore docks. The D., M. & N. have a two per cent. grade, 105 ft. to the mile down the hill. Except for this hill — and this is only against empties — the D., M. & N. has no excessive grades from the mines to the docks. They have a high type double-track line, with many miles of rock ballast and steel ties. The Great Northern has a very flat grade line. From the mines to the Superior yard, the heaviest grade is 0.25 per cent., or 13 ft. to the mile. The Great Northern is famous for its low-grade lines.

The rail rate was formerly 80c. per ton unloaded in the ore docks. This was reduced a few years ago to 60c. The annual working season is about two hundred days, and during the balance of the year the entire plant is idle.

D., M. & N. ore docks, Figs. 6 and 7, are in Duluth, the four docks being about the same length as the Great Northern Docks. Duluth, you know, is situated on the edge of a very steep hill, about 300 ft. high, and the city runs along the lake shore for miles. It is a common saying that Duluth is 40 miles long, a half mile wide and a mile high. About 20 million tons are shipped through these docks per year.

Duluth & Iron Range has its docks at Two Harbors, about 30 miles east of Duluth. About 10 million tons are shipped from here, of which about 2 million is from the Vermilion range.

G. N. Ore Dock No. 3, under construction, is shown in Fig. 8. All work is done in the winter, when the docks are idle and when there is enough ice to work from.

While I was with the Great Northern, I built all of Dock No. 1, and doubled the length of No. 3, and rebuilt half of No. 2. All of these docks are about the same type of construction.

Dock No. 1 is 2 244 ft. long, 73 ft. high above water line, and 63 ft. wide; contains 17 million ft. of fir timber, and rests upon 16 000 piles 40 ft. to 80 ft. long. All timber was shipped 1 800 miles from Puget Sound points, requiring 1 000 cars. This timber would make a board walk 12 ins. wide from Boston to San Francisco. The piles, if placed end to end, would reach 170 miles. It cost a little over $1 000 000. We started to remove the old dock No. 1, containing about 6 million feet of timber, December 1, and started to drive piles in January; and the new dock was in service June 20.

These docks will load a boat very rapidly. The steamer *Wolvin* was loaded with 10 000 tons of ore in forty minutes at the G. N. docks, some years ago, and I think the record has since been beaten.

G. N. Ore Dock No. 4, Fig. 9, was the first concrete steel ore dock. It is about 1 800 ft. long and has only one post under a pocket, instead of 18 in the timber docks. Each post, however, is 36 ins. by 84 ins. It rests on a sand filled crib.

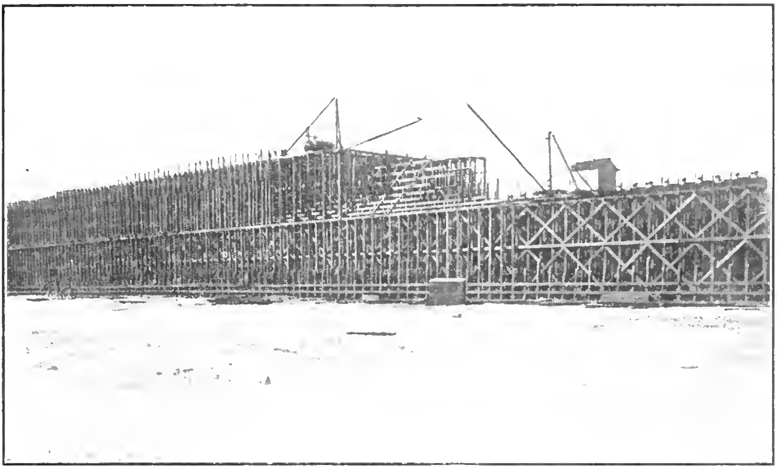

Fig. 8. Ore Dock No. 3 of the Great Northern Railway, under Construction.

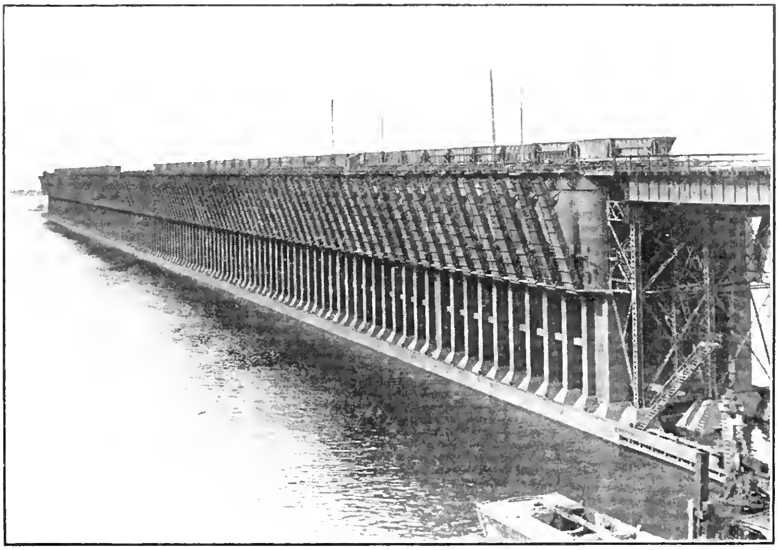

Fig. 9. Ore Dock No. 4 of the Great Northern Railway, at Allouez Bay, Superior, Wis.

The top is of steel, of which there are 9 000 tons. The dock cost about $1 600 000. The depth of water in the slips is 24 ins. to 25 ft. Although there is no tide in Lake Superior, the depth of water will vary from year to year by several feet.

The lake ore boats are under-engined, and when unloaded are hard to manage. These boats usually come up from the lower lake ports loaded with coal, and return loaded with ore, grain, etc. A great many million tons of coal pass through the Duluth-Superior Harbor.

In 1917, the operation of boats was placed under a central control, and as an emergency measure the ore was placed in charge of a committee. Under this plan, ore was allotted to docks in accordance with the supply of railroad cars. In 1918, this plan is to be considerably broadened. This is a war measure, and considerably different from normal operation.

Those of you who are familiar with the operation on the Mesabi will appreciate that I have only made a hurried sketch of the whole process, as the operations are too extensive and vast to even grasp after visiting the district many times.

I wish to thank Mr. Irwin, of the Bay State Street Railway Company, Mr. Seward, general agent, and Mr. Hogeland, chief engineer of the Great Northern, and the editor of the *Iron Trade Review*, for their courtesies in furnishing me with data and photographs.

Vol. V MARCH, 1918 No. 3

BOSTON SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

THE HYDRAULIC LABORATORY OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

By George Edmond Russell,* Member of the Boston Society of Civil Engineers.

In presenting this paper to the Society, the author wishes to disclaim any intention of offering a detailed description of the Institute's new hydraulic plant, inasmuch as to do so would necessitate drawings which at this time are neither available nor can be prepared. The present object is to give such general facts and descriptions as will enable the engineering profession to learn of the beginnings which have been made and enlist its interest in the further development of this important project.

The laboratory, Fig. 1, is situated in that portion of the buildings which flanks the west side of the Main Court, and occupies, jointly with the steam and compressed air laboratories, the entire basement and two floors of the building. The portion devoted almost wholly to hydraulics, measures about 165 ft. in length, by 60 ft. in width, and includes the entire basement within this area and two half floors extending from the court wall to

* Associate Professor of Hydraulic Engineering, Massachusetts Institute of Technology.

Note. This paper, which will not be presented at a meeting of the Society, was intended to accompany the papers on the construction of the buildings printed in the January issue of the Journal, but was delayed in preparation.

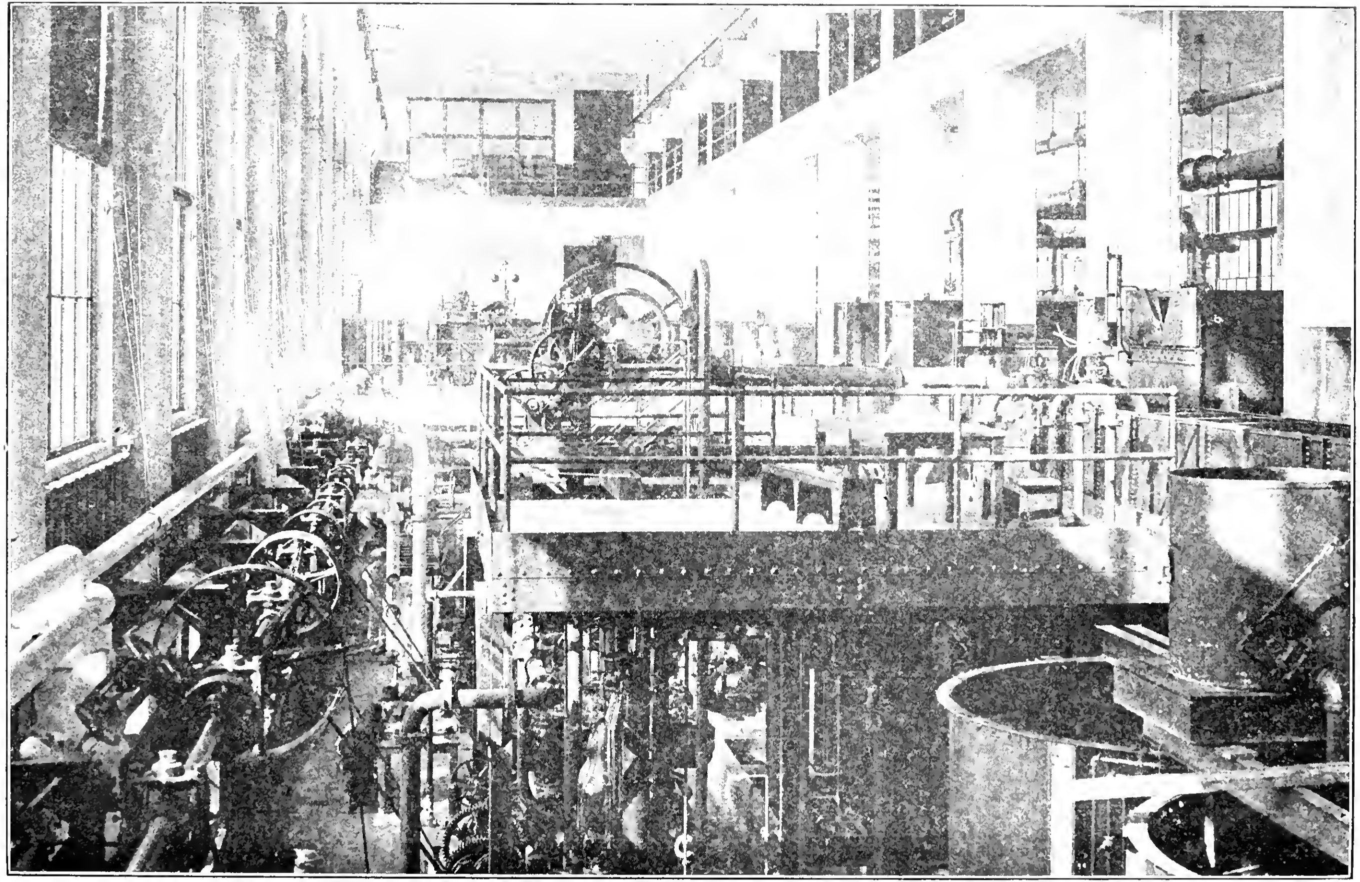

FIG. 1.—GENERAL VIEW OF LABORATORY

the center line of columns. Above one half of the basement floor there was left an open space extending through the two floors above, to serve as a craneway for the easy handling of the heavy pieces of apparatus with which the laboratory is equipped.

The general scheme of arrangment comprises the following

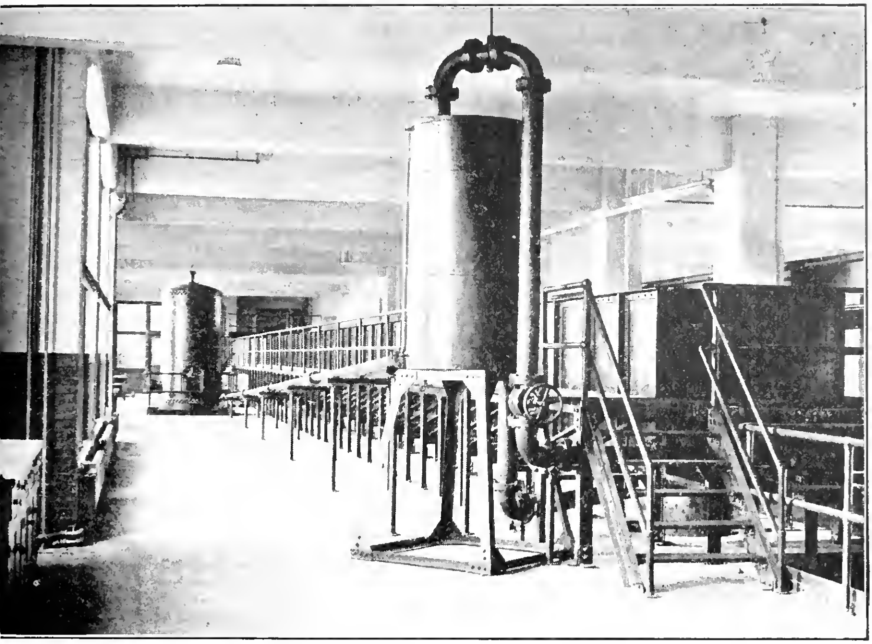

FIG. 2. STEEL HEAD RACE IN THIRD FLOOR, SHOWING RAM OUTFIT IN FOREGROUND AND TOP OF PRESSURE TANK IN BACKGROUND.

details: A system of canals in the basement floor for receiving and storing water taken from the Charles River Basin; a diversified collection of pumps to serve as objects of tests and to furnish the water through the distributing systems to the various experimental pieces of apparatus; a distributing system embracing piping for high- and low-pressure service, and both concrete and steel canals; and, finally, a collection of apparatus to be

used in connection with tests, illustrative work and original investigations.

The canal for storing the water is rectangular in cross-section, varying in width from 5 to 8 ft. and having an average depth of about 5 ft. It is endless, being arranged on the four sides of a rectangle whose length is 132 ft. and width 35 ft., and is so designed that it may be possible, by operating a large pumping unit, to simulate within it conditions of artificial stream flow. In all experimental work, water will be drawn from this canal and finally returned to it after passing through the apparatus which is being used. Its filling is accomplished by a gravity connection with the Charles River Basin aided by pumping.

In addition to the canal are two pits, 30 ft. deep, directly connected by means of valves with the water in the river basin. These serve as suction wells for investigating the performance of pumps under different conditions of suction head, the water level in them being controlled by the inlet valves which are opened or closed as the pump delivery is changed. By placing the pump to be tested on a raised platform above the pits, the suction head may be made as much as desired.

The pumping equipment consists of 15 units embracing numerous distinct types of varied size and capacity. The largest of these is a Worthington 30-in. centrifugal, directly connected with a 350 h.p. Ball angle compound engine. This unit is capable of pumping 22 000 gals. per minute against a head of 45 ft., and will be used for supplying water to the turbine testing flume. The two-stage type is represented by an 8-in. De Laval, steam turbine driven pump, and the three-stage by a 4-in. Jeansville pump operated by a Terry steam turbine.

The largest plunger pump is a Warren Duplex, 24 ins. by 15 ins. by 24 ins., designed for a maximum discharge of 1 500 gals. per minute against a 600-ft. head. This pump and the Jeansville centrifugal are used in connection with the compression tank to furnish water in all experiment work demanding high heads.

Of special interest are the arrangements for the testing of water turbines. While, owing to the exigencies of the war, the equipment is not yet complete, the major portion is in place,

and plans are ready for going ahead with the work in what is hoped to be the near future. Water from the large 30-in. centrifugal flows through a 30-in. Venturi meter, and by a vertical riser to the third floor of the laboratory, where it is delivered into a rectangular steel channel of 25 sq. ft., cross-section, Fig. 2. In this it runs for a distance of 135 ft. to the open flume

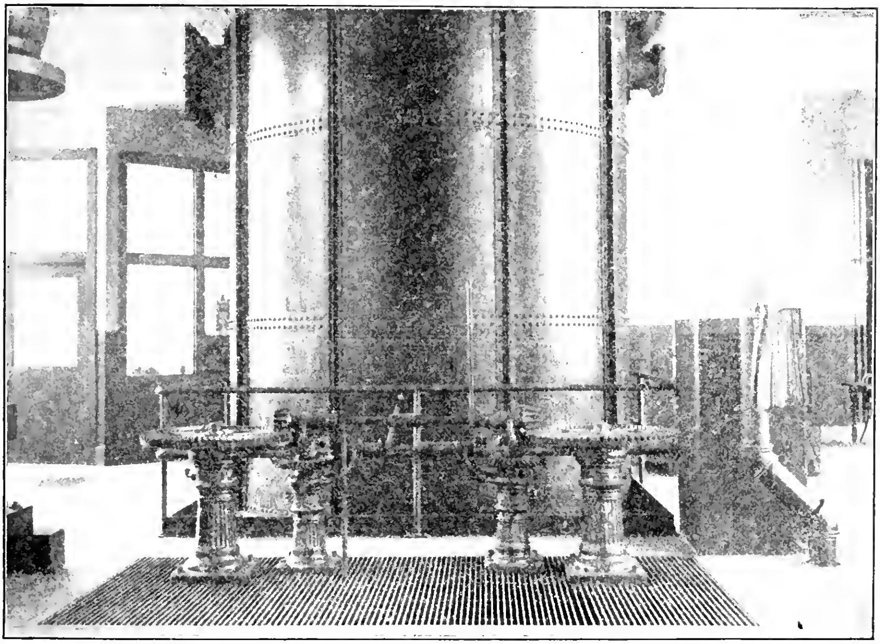

FIG. 3. BASE OF STEEL TURBINE FLUME AND HAND CONTROL GATES.

containing the turbine. The flume, Fig. 3, is an upright cylindrical steel tank, 12 ft. in diameter and 22.5 ft. high, with its base resting on the second floor of the laboratory. In its bottom is set the turbine, which discharges through a draft tube into a concrete tail race below. The back and side walls of the race are carried up from the basement to the second floor, and a large cast-iron gate placed across the race so that the water level immediately below the wheel and about the draft tube can be held at any desired level before being discharged down the race.

The design of the gate is peculiar, it being arranged to move up or down in the usual way, permitting the escape of water beneath it, but also provided with a series of long horizontal openings or sub-valves, which are operated by a secondary stem and so designed as to open successively, thus allowing close control of the water level. The stems of the valves reach through the floor above, where they are operated by the ordinary hand gate-jack (Fig. 3).

On passing the gate, the water flows through baffles and is then quieted in a straight reach of about 72 ft. before passing over the weir at the end of the race. From the weir it drops into the rectangular storage canal, completing the cycle of flow.

The weir just mentioned is a standard suppressed weir, 10 ft. in length and 5 ft. 6 ins. in height, although the height is quite easily alterable so as to permit changing the velocity of approach. One interesting feature connected with it is the fact that, in inserting the piezometer connections in the sides of the concrete channel, it was thought wise to make three separate sets of connections, each one duplicating the conditions of the Francis, Stearns and Bazin piezometers, with respect to size and location. Three separate hook gage pails allow the simultaneous measurement of the three heads. Already some work has been done by advanced students in comparing results so obtained, and, while the investigation has only begun, it looks as if interesting and perhaps valuable results might be reached.

Although the weir was designed to act as the standard mode of measurement in all turbine tests, it should be noted that a 30-in. Venturi meter was placed in the supply line and a third measurement is possible in the head race, where current meters may be used. At a future time it is proposed to install here a moving screen which shall hang vertically in the channel, fit with small clearance the cross-section of the same, and move down its length on a supporting track with the mean velocity (assumed) of the water. Experiments, at Wisconsin, and on a small scale at the Institute, already indicate that a high degree of precision may be thus reached in measuring mean velocities in artificial channels. It would seem, therefore, as if the measurement of the quantity of water passing the turbine might be precisely made.

The power output of the wheel will be measured by an Alden absorption dynamometer mounted directly on the turbine shaft. The setting of the turbine is similar to that at the Holyoke Flume, the wheel being hung on a suspension bearing which is capable of vertical adjustment.

The wheel to be first installed is an 18-in. S. Morgan Smith

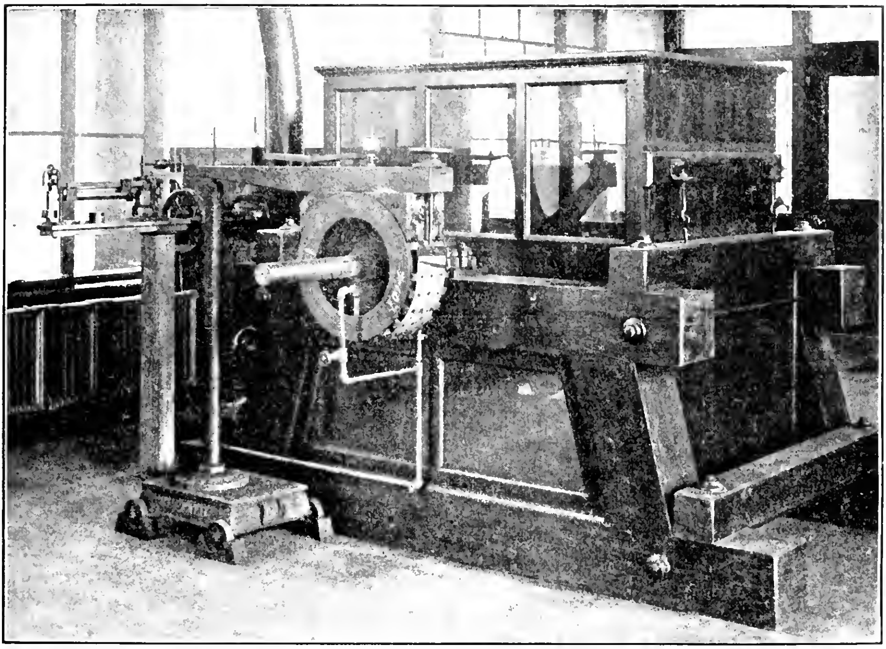

FIG. 4. PELTON WHEEL UNIT WITH BRAKE.

wheel, specially designed and donated by the makers for the purpose of experimental work. It has been tested at Holyoke, so that any future work done here can be compared with results obtained under Holyoke conditions. The maximum head which can be obtained in the flume will be about 34 ft., this being divided into a pressure head above the wheel of 22.5 ft. and a draft head of 11.5 ft. With this fall and a maximum discharge of 50 sec. ft., a gross power of about 193 h.p. may be obtained.

At present the laboratory is equipped with three turbines of the tangential type, one an American 30-in. wheel, a Pelton 36-in. wheel, Fig. 4, and a modern Pelton-Doble wheel, 24 ins. in diameter. These are nozzle-fed with water pumped into the pressure tanks, of which there are two (Fig. 5). Both of the latter are cylindrical, set vertically, and capable of furnishing

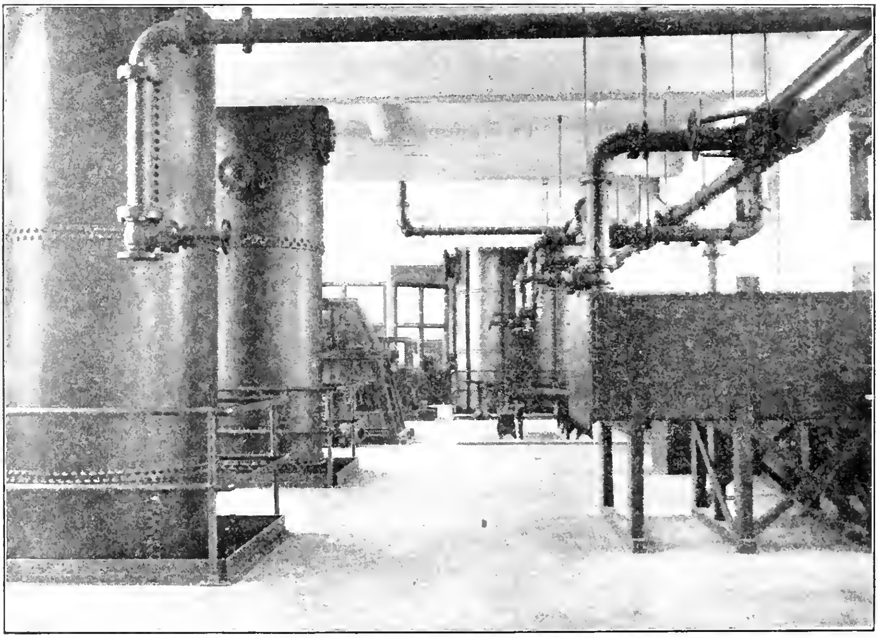

Fig. 5. Pressure Tanks and Weir Boxes on Second Floor.

heads as high as 600 ft. Assuming that, under high pressures, the water will gradually absorb the air cushion at the top of the tank, arrangements will be made for supplying compressed air to make up the loss so incurred.

The tanks are equipped with openings at different levels, to permit the insertion of experimental orifices, nozzles, mouthpieces, and any apparatus for using water under a wide range of head. The position of the tanks is such that their discharge

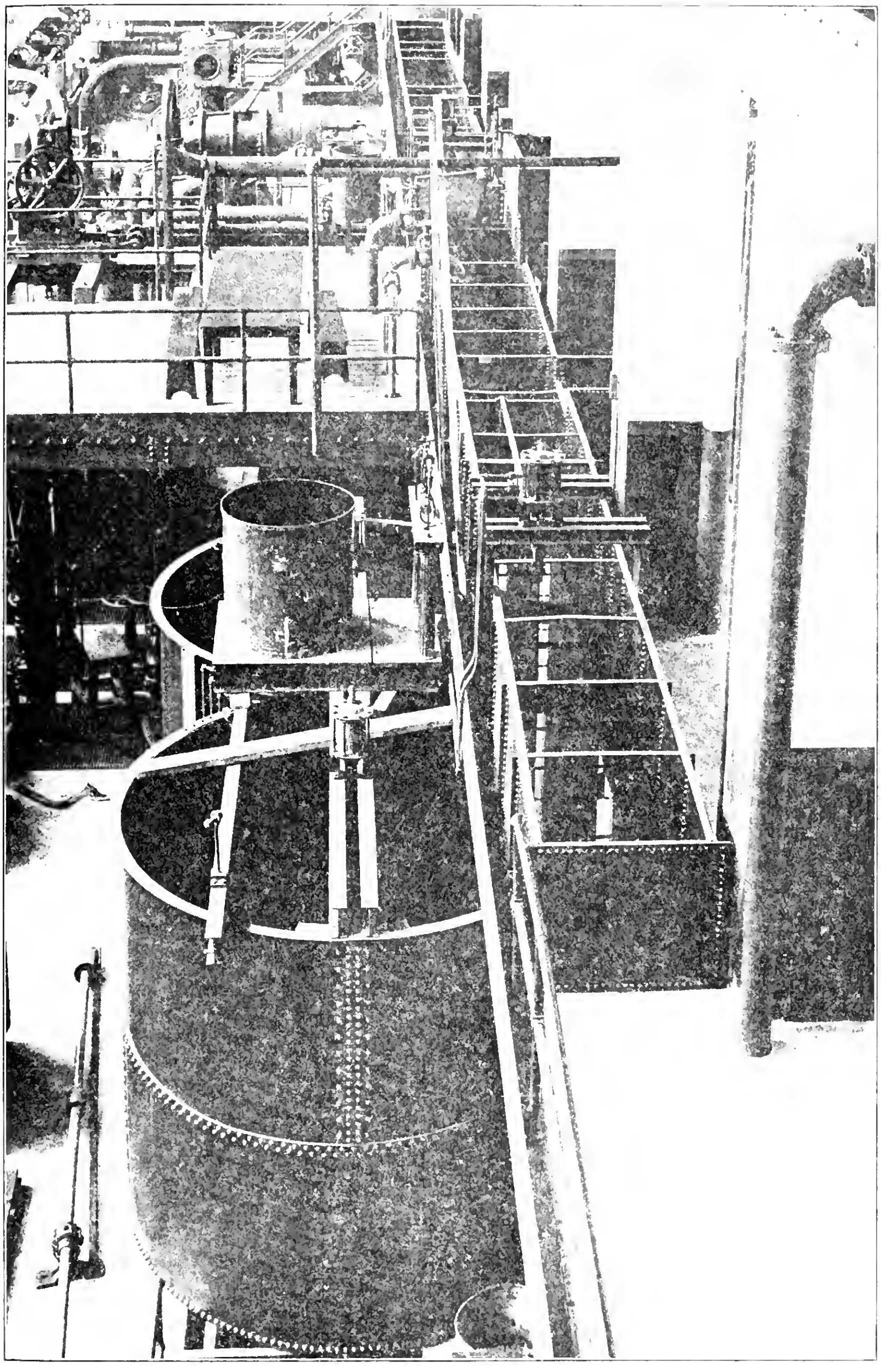

FIG. 6. NEAR VIEW OF COLLECTING TROUGH, SHOWING GATE-OPERATING VALVE AND CALIBRATED TANK.

valves are directly over the canals in the basement. The larger of the two tanks is 35 ft. high, extending through the upper floor of the laboratory, thus giving opportunity for high-pressure work on all floors. This tank is 6 ft. in diameter and made from 1-in. steel plate.

As far as possible, the discharge from the various pumps and wheels will be measured over weirs, but arrangements have been made whereby all but the largest pieces of apparatus may have their discharges measured in calibrated steel tanks which rest on the basement floor and discharge into the canal (Fig. 6). There are four of these tanks, — two 10 ft. in diameter and 12 ft. tall, each with a capacity of 7 000 gals., and two 6 ft. in diameter and 10 ft. tall, with a capacity of 2 100 gals. each. Above these tanks runs a steel collecting trough, easily accessible from different parts of the laboratory, into which water comes from any particular piece of apparatus and from which it will flow through valves into the tanks below. These valves, as well as those which empty the tanks, are operated by water pressure, and the design makes it possible for the operator to shift the discharge quickly from one tank into another or to empty a tank without moving from his position.

No equipment has so far been installed for pipe experiments, but it is planned to utilize space on the third floor for this purpose, where connection can be easily made with the large pressure tank which rises from the basement through both floors. Here, too, will be installed the apparatus for the calibration of nozzles. At present there is on this floor, beside the steel channel forming the head race to the turbine flume, two rams which operate under a head of about 8 ft.

This latter is obtained by pumping into an elevated steel tank equipped with a constant level overflow. Waste water from the rams, and also the discharge from the same, is returned to the basement and weighed in large tanks. At present the equipment is composed of a twin Gould ram and one Rife.

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BOSTON SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

THE EFFECT OF HEATING CONCRETE MATERIALS IN THE MIXER.

By H. E. Sawtell,* Member Boston Society of Civil Engineers.

The following is a description and a statement of the results of a test, made for Mr. Charles T. Main, which may be of value to engineers, for the purpose of determining whether heating, in the mixer, of materials by a method being used during cold weather, had any effect on the strength of the concrete.

The apparatus used consisted of a small tank for kerosene, a pump to compress air in the tank, and a connecting pipe to a burner, fastened to the mixer just over the receiving chute.

The kerosene was forced by the compressed air through the connecting pipe into the burner, where it burned with a blue flame. The flame then passed down a flattened pipe into the mixer. The flattened pipe stopped just inside of the mixer at the top of the opening, and the flame shot from there to the center of the mixer. The flame, after leaving the pipe, was about 9 ins. wide, 6 ins. thick, and 1 ft. long.

The concrete materials entered under the flame, and apparently did not come in direct contact with it at any time. The air in the mixer did get very hot, however, and the concrete

* Structural Engineer, with Charles T. Main, 201 Devonshire Street, Boston.

Note. This paper will not be presented at a regular meeting of the Society, but discussion is invited, to be received by W. L. Butcher, Editor, 715 Tremont Temple, Boston, before May 10, 1918, for publication in a subsequent issue of the Journal.

dried out so fast that it was necessary to add water repeatedly during the mixing. As the effect of the rapid heating and drying out was doubtful, it was decided to make a test.

Six cylinders, made of 1 : 2 : 4 concrete, each 8 ins. in diameter and 16 ins. high, were made as follows.

Sand and stone were put into mixer, and turned for ten minutes. The cement was then added, followed by the water. The mixer was started at 5.40 P.M.

First cold sample taken at 6.10 P.M.; temperature 48 degrees Fahr.

Second cold sample taken at 6.15 P.M.; temperature 48 degrees Fahr.

Third cold sample taken at 6.25 P.M.; temperature 50 degrees Fahr.

Started heater at 6.25, and temperature at start was 50 degrees Fahr.

First hot sample taken at 6.45 P.M.; temperature 92 degrees Fahr.

Second hot sample taken at 6.50 P.M.; temperature 98 degrees Fahr.

Third hot sample taken at 6.55 P.M.; temperature 95 degrees Fahr.

All temperatures were taken by inserting a thermometer into the concrete of each cylinder as soon as filled. The mixer was run continuously with the same batch from 5.40 to 6.55 P.M.

It was necessary to add a little water before taking the third hot sample, which accounts for the drop in temperature.

The three cold cylinders were marked 2, 4 and 6 respectively, while the three hot cylinders were marked 1, 3 and 5 respectively.

All cylinders were then placed in a damp atmosphere at the bottom of an excavation 10 ft. deep and covered with canvas. In ten days they were removed to an unheated room, where they remained for about a week, after which they were carefully boxed for shipment and sent to Professor Hayward at the laboratory of the Massachusetts Institute of Technology, for testing. They were crushed at the end of twenty-eight days with the following results.

No. of Cylinder.	Temperature.	Maximum Load in Lbs.	Compressive Strength. Lbs. per Sq. In.
1	Hot	71 000	1 412
2	Cold	137 000	2 736
3	Hot	65 400	1 303
4	Cold	144 000	2 865
5	Hot	40 000	795
6	Cold	117 400	2 336

The average strength of the hot concrete was about 44 per cent. of that for the cold concrete.

Professor Hayward's report states that cylinders 1, 3 and 5 contained a large number of surface cracks, of varying depth.

The bonding of the aggregate in numbers 1 and 3 cylinders was not nearly as good as in the case of numbers 2, 4 and 6, and the bonding of the aggregate in number 5 was especially poor.

It appears from these tests that there is a marked reduction of strength in concrete when heated by the method described; but, as it may be unsafe to form judgment based on such a small number of tests, we should like to see the matter investigated further.

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BOSTON SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

DISCUSSION OF THE FOUNDATIONS OF THE NEW BUILDINGS OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

By J. R. Worcester,* Member Boston Society of Civil Engineers.

The report of the experimental work in connection with the foundations of the Technology buildings is a valuable addition to the meager literature upon pile foundations, and the care taken in testing the ground and recording the results of the tests gives the information thereby obtained unusual weight.

The pile driving and load tests recorded do not make entirely clear the reasons which led to some of the rules adopted, though undoubtedly the latter were justified by information not easily obtainable from the reports. For instance, how was it determined that spruce piles could not have been driven everywhere in place of oak? According to Rules 1 and 2, it was determined to use oak whenever a 2 300-lb. hammer falling 10 ft. produced a penetration of less than $1\frac{1}{4}$ ins. The first ten piles of Group A, which broke, were apparently subjected to considerably heavier driving than this, and we do not find evidence

* Of J. R. Worcester & Co., Consulting Engineers, 79 Milk Street, Boston.

that they could not have been driven with a lesser fall far enough into a " hard " soil to have carried the required loads with safety.

It would not appear that any great advantage was obtained from the attempt to determine the load causing $\frac{1}{16}$-in. settlement. Comparing these loads with the ultimate capacity, we find a very variable factor of safety, as shown in Table 1.

TABLE 1.

Pile No.	Load Causing $\frac{1}{16}$-In. Settlement.	Maximum Load.	Factor of Safety.
14 a	11 000	77 400	7.0
2 a-4	14 000	29 860+	2.1+
12 d	18 000	89 800	5.0
2 a-2a	20 000	62 400+	3.1+
12 g	30 860	83 500	2.7
11 a	25 600	77 400	3.0
10 a	25 760	59 000+	2.3+
13 g	16 000	43 000+	2.7+
11 d	18 000	64 000	3.6
n 8	19 600	87 000	4.4

It is evident that the load at the $\frac{1}{16}$-in. settlement is little indication of the maximum capacity. There are two good reasons for this. In the first place, the elasticity of the pile must affect this observation to a marked degree, especially when the support is mainly near the tip and there is a considerable length in material having little supporting power. Roughly speaking, a length of 20 ft. under a load of 20 000 lbs. would cause an elastic shrinkage of $\frac{1}{10}$ in. This indicates that the settlements of $\frac{1}{16}$ in. recorded may very easily be entirely elastic, and not due to any yielding of the bottom. Another reason why $\frac{1}{16}$ in. is not a very useful point in the settlement upon which to rely, is the difficulty of observing the settlements with sufficient accuracy.

It would appear that the load at $\frac{1}{4}$ in. is more reliable and useful as an index of the capacity. Table 2 gives the results of the same tests as before arranged with regard to their capacity at $\frac{1}{4}$-in. settlement.

TABLE 2.

Pile No.	Load Causing $\frac{1}{4}$-In. Settlement.	Maximum Load.	Factor of Safety.
14 a	73 000	77 400	1.06
2 a-4	28 000	29 860 +	1.06 +
12 d	75 200	89 800	1.19
2 a-2a	43 000	62 400 +	1.45 +
12 g	66 000	83 500	1.26
11 a	43 500	77 400	1.78
10 a	41 100	59 000 +	1.44 +
13 g	28 000	43 000 +	1.54 +
11 d	28 000	64 000	2.29
n 8	53 700	87 000	1.62

So far as can be judged from these tests, it would be entirely safe to allow for a working load one half that causing $\frac{1}{4}$-in. settlement. The factor of $2\frac{1}{2}$ actually used was undoubtedly conservative.

In the design of the concrete footings, it is not clear why it was thought necessary to increase the depth on account of a possibility that piles immediately under the load will be stressed somewhat higher than those at the edges. Even if this were the case, — and it is by no means certain that it would be, — it is hard to see how the unequal distribution of the load would have anything but a beneficial effect upon the footing.

In his discussion, Mr. L. M. Hastings has touched upon the vital question which must occur to any one familiar with the history of structures in the locality where these buildings have been placed. It will be a very pleasing surprise if a gradual settlement of the whole group does not develop, through the subsidence of the glacial deposit below the mud. Such a settlement might not be noticeable or injurious if it were uniform over the hole area, but the area covered by the connecting buildings is so large that it would appear hardly probable that they could all move together. The outcome will be awaited with great interest.

MEMOIRS OF DECEASED MEMBERS.

OTIS FRANCIS CLAPP.*

Otis Francis Clapp, son of James Otis and Lucia Kingman Clapp, was born in Boston, Mass., September 26, 1843, and died at Providence, R. I., March 3, 1917. He was educated in the public schools and Hunt's Academy at North Bridgewater, now Brockton, Mass. He entered the office of Shedd and Edson in Boston, where he received his early training in engineering, and in 1867 was sent from that firm's office to Providence, R. I., to make the preliminary surveys for the first municipal water-works system, which provided for taking the water supply from the Pawtuxet River and which later was adopted.

In 1872 Mr. Clapp was placed in charge of preparing plans for a sewerage system for the city of Providence. A large part of the city's sewers and the precipitation works for the disposal of sewage were constructed under his direction.

In May, 1897, he was appointed city engineer to succeed J. Herbert Shedd, resigned, an office which he held for eighteen successive years. He was then appointed first assistant in the city engineer's department on special work in connection with the improvement of the Moshassuck River channel, and held that position for nearly a year, when he resigned on account of failing health.

Mr. Clapp was connected with the engineering work of the city of Providence for more than fifty years, being more particularly interested in water works and sewers. He joined the Boston Society of Civil Engineers in 1888, and was Vice-President of the Society in 1904 and 1905, and at the time of his death he was a member and a director of the American Society of Civil Engineers.

In November, 1869, he married Anna Isabella Sweetland, whom he survived about two years.

Mr. Clapp was a man of pleasing personality, modest and unassuming in manner, and of a genial temperament which had attracted to him many friends.

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* Memoir prepared by Wm. D. Bullock and Irving S. Wood.

HENRY AUGUSTUS HERRICK.*

Henry A. Herrick was born November 26, 1861, at Brooklyn, N. Y.

His parents were Henry Walker Herrick and Clarrissa Harlow Parkinson.

His parents moved to Manchester, N. H., when he was four years old. He was educated in the public schools in Manchester, graduating from the high school at the age of nineteen years.

His first work after graduation was with the Amoskeag Manufacturing Company at Manchester, in connection with the design, construction and equipment of cotton mills. He was later, in succession, engaged in similar work at the Methuen Mills, Methuen, Mass.; at Willimantic, Conn.; with F. P. Sheldon, mill engineer, Providence, R. I.; and at the Schuylerville Mills.

In 1890 he went to Spokane, Wash., where he designed and supervised the construction of the dam and power station which is still in operation.

On January 14, 1891, he was married and went to Great Falls, Mont., where he designed and supervised the construction of the Black Eagle Falls Dam and power plant for the Boston and Montana smelter.

In the latter part of 1895 he became associated with Dean & Main, engineers, and was engaged in the design and supervision of construction of many textile and other industrial plants. Upon the dissolution of this firm in 1907, he continued his association with Charles T. Main.

The most interesting, valuable and effective work was done by Mr. Herrick in the last ten years of his life, during which time he had charge of the design and construction of some of the largest and best hydro-electric developments in the country; namely, the Rainbow Falls development and the Great Falls development on the Missouri River near Great Falls, Mont., the Thompson Falls development on Clarks Fork of the Columbia River, at Thompson Falls, Mont., and he was just nearing the completion of his work on the Holter development, near

* Memoir prepared by Chas. T. Main.

Helena, Mont., when he was stricken down by heart failure and died immediately. All of these developments formed a part of the system of the Montana Power Company, and aggregated about 250 000 h.p.

During the time that the above-mentioned work was in progress, and between the ending of one and beginning of another undertaking, he made many examinations and reports on other projects and acted as consulting engineer on several.

Mr. Herrick had developed a systematic analysis of dams, based on his many years of close study and experience in designing such structures. All of the many fundamentals, such as geological formation, seepage, drainage, upward pressure, shock and dissipation of energy due to overflow, flood conditions, etc., received proper consideration in his analysis.

His early training in design and construction enabled him to design the buildings for power stations in a most acceptable manner. He mastered the electrical problems with great ease.

He was a great student, and a fine mathematician, and one of the best of the type represented by self-educated engineers. His character was of the highest, and his dealings with men above and below him were always characterized with fine courtesy and uprightness.

He was a member of the Boston Society of Civil Engineers, joining November 15, 1911, and of the American Society of Civil Engineers, which he joined in 1890. He was also a member of the Engineers Club, Boston; the Fresno Club, Fresno, Calif.; Silver Bow Club, Butte, Mont.; and other societies.

His principal recreation was trap and target shooting, hunting and fishing, and he took as much pleasure in anticipation as in the rare actual outings which his busy life allowed him.

Vol. V APRIL, 1918 No. 4

BOSTON SOCIETY OF CIVIL ENGINEERS
FOUNDED 1848

PROCEEDINGS

NOTICE OF REGULAR MEETING.

A REGULAR meeting of the Boston Society of Civil Engineers will be held on

WEDNESDAY, APRIL 17, 1918,

at 7.45 o'clock P.M., in CHIPMAN HALL, TREMONT TEMPLE, BOSTON.

Commander H. R. Stanford, Civil Engineer, U.S.N., will give a talk on "The Pearl Harbor Dry Dock, Hawaii." The talk will be illustrated with lantern slides.

S. E. TINKHAM, *Secretary*.

PAPERS IN THIS NUMBER.

Address at the Annual Meeting. George C. Whipple.

"Economy in the Use of Fuel in Power Stations." Chas. H. Parker.

Memoir of deceased member.

Contributors are hereby notified that proof will not be submitted to them for examination unless requested before the 10th of the month preceding the month of publication.

MINUTES OF MEETINGS.

BOSTON, MASS., February 27, 1918. — A special meeting of the Boston Society of Civil Engineers was held this evening at the Society rooms, and was called to order by the President, George C. Whipple, at 7.45 o'clock.

There were 27 members and visitors present.

Mr. Clayton W. Mayers, of the Aberthaw Construction Company, was present and read a paper entitled, "Economic Design of Concrete Buildings." This paper was printed in the February, 1918, number of the JOURNAL.

The discussion following the reading of the paper was opened by a short communication from Mr. Joseph R. Worcester, which was read by the Secretary.

Others who took part in the discussion were Burtis S. Brown, John R. Nichols, Leslie H. Allen and Clayton W. Mayers.

After passing a vote of thanks to Mr. Mayers, who is not a member of the Society, for his courtesy in presenting so valuable and interesting a paper, the Society adjourned.

S. E. TINKHAM, *Secretary.*

BOSTON, MASS., March 20, 1918. — The seventieth annual meeting of the Boston Society of Civil Engineers was held at the Boston City Club, Ashburton Place, Boston, on Wednesday, March 20, 1918.

The thirty-sixth annual dinner which preceded the business meeting was served in the auditorium of the Clubhouse at half past one o'clock, the President of the Society, Prof. George C. Whipple, presiding.

During the serving of the dinner, Past President Richard A. Hale read the Roll of Honor of the Society, a list of its members who are serving in the army or navy of the United States or any of its allies. This list is printed in the April number of the JOURNAL.

At the call of the President, the Secretary read extracts from letters written by three members who are with the American Expeditionary Force in France, Captain John F. Osborn, 101st Engineer Regiment; Captain Lewis E. Moore, Engineer Reserve

Corps, and Major Benjamin W. Guppy, 114th Engineer Reserve Corps. For these extracts from personal letters the Society is indebted to Mr. C. W. Sherman, Mrs. L. E. Moore and Mr. A. B. Corthell.

The Society was honored by the presence, for a short time, of His Honor Andrew J. Peters, Mayor of Boston, who made a brief address extending the hearty welcome of the City to the members of the Society.

The President then introduced Mr. Robert Ridgway, of New York, Engineer of Subway Construction, who gave a most interesting talk on "The New York Subways," which was very fully illustrated with lantern slides. At the conclusion of the talk, on motion of Past President Eddy, a unanimous vote of thanks to Mr. Ridgway was passed for his courtesy in presenting to the Society so graphic a description of the New York subway work.

At five o'clock the business meeting was called to order, in Rooms B and C of the Clubhouse, by President Whipple.

The record of the February meeting of the Society was read and approved.

The President announced the death of Thomas Aspinwall, a member of the Society, which occurred on March 2, 1918, and by vote the President was requested to appoint a committee to prepare a memoir. The President has named as the committee, Messrs. Edwin H. Lincoln and Desmond FitzGerald.

The annual report of the Board of Government was read by the Secretary, and by vote was accepted and ordered printed in the JOURNAL.

On motion of Mr. C. W. Sherman, it was voted unanimously: That the dues for the year 1918–19 be abated to all members in the military or naval service of the United States or its allies; and that a sum not exceeding one thousand dollars be appropriated from the income of the Permanent Fund to reimburse the Current Fund of the Society for the resulting loss.

The Treasurer read his annual report, and by vote it was accepted and ordered printed in the JOURNAL.

The Secretary read his annual report which was also accepted and ordered printed in the JOURNAL.

The Librarian read the annual report of the Committee on the Library, which was accepted and ordered printed in the JOURNAL.

Mr. David A. Ambrose, chairman of the Committee on Social Activities, read the report of that committee, and by vote it was accepted and ordered printed in the JOURNAL.

Mr. C. W. Sherman, in the absence of its chairman, presented and read the report of the Committee on Run-off Available for Water Power Purposes. The report was accepted as a progress report and ordered printed in the JOURNAL and the committee continued.

By vote, the appointment of the several committees of the Society was referred to the Board of Government with full powers.

The tellers of election, Messrs. Albert F. Brown and William A. Bryant, submitted the result of the letter ballot for officers of the Society for the ensuing year, and in accordance with their report, the President announced that the following officers had been elected:

President — Charles M. Spofford.

Vice-President (for two years) — Leonard C. Wason.

Secretary — S. Everett Tinkham.

Treasurer — Frank O. Whitney.

Directors (for two years) — John L. Howard and Edwin H. Rogers.

Members of Nominating Committee (to serve two years) — Charles T. Main, Edmund M. Blake and Arthur T. Safford; (to serve one year) — George A. Carpenter, Edgar S. Dorr and Henry B. Wood.

The Secretary stated that a request had been received from the committee in charge of the campaign for the Third Liberty Loan in Boston and the proposed parade in its interest to be held in Boston on April 6 next, asking the Society's assistance in this work. After a discussion it was voted to refer the matter to the Board of Government with full powers.

The retiring President, George C. Whipple, then delivered the annual address of the president, which will be printed in the April number of the JOURNAL.

The meeting then adjourned to participate in the annual smoker which was held in the auditorium of the Club.

The smoker was of the same general character as those of former years. Music was furnished by a Jazz Band, and light refreshments were served.

The singing of the old songs and several new ones which had been written by members for the occasion was more enthusiastic if possible than ever before. The entertainment was of a more varied character than usual. Two sets of motion pictures were shown, depicting war scenes, one entitled, "The German Curse in Russia," and the other, "Italy on the Firing Line."

Two entertainers were also presented, — Mr. Darling, "the cartoonist and mud-pie man," and Mr. Lorraine, a monologist and imitator.

A new feature was inaugurated at this smoker, the first annual line-up, an informal reception to the new officers and members who have joined the Society since the last annual meeting.

The attendance at the several functions, while not as large as last year, was more than 260.

S. E. TINKHAM, *Secretary*.

ANNUAL MEETING OF THE SANITARY SECTION.

BOSTON, MASS., March 6, 1918. — The annual meeting of the Sanitary Section of the Boston Society of Civil Engineers was held this evening in the Society Library in Tremont Temple. The meeting was called to order at 7.40 o'clock by Chairman Frank A. Marston. The minutes of the January meeting were read and approved. The annual report of the Executive Committee was read by the Clerk, and it was voted that it be accepted and placed on file.

The committee appointed to study and collect data upon the distribution of excessive rainfall in Boston and vicinity was not ready to report any progress, which was also the case with the Committee on Outfall Sewers.

Mr. Robert Spurr Weston, chairman of the Nominating

Committee, presented the names of the candidates for officers of this section to be filed at this time, as follows:

For Chairman — Almon L. Fales.

For Vice-Chairman — Edgar S. Dorr.

For Clerk — Henry A. Varney.

For additional members of the Executive Committee:

William Nelson.

Alfred O. Doane.

Arthur L. Gammage.

There were no other nominations. It was voted that the Clerk be instructed to cast one ballot for the officers as nominated, and they were declared elected for the ensuing year.

The paper of the evening, "Economy in the Use of Fuel in Power Stations," was read by Charles H. Parker, superintendent of the Generating Department, Edison Electric Illuminating Company of Boston. The paper, which was illustrated by a reflectroscope, was of great interest to those present and was discussed by Mr. Doane and others.

There were fifty-three members and guests present.

Through the courtesy of the Edison Electric Illuminating Company about thirty members inspected the company's Power Plant at L Street, South Boston, during the afternoon. A vote of thanks was extended to Mr. Parker for the very valuable paper, and to the Edison Company for the privilege of inspecting their plant.

The meeting was adjourned at 9.50.

HENRY A. VARNEY, *Acting Clerk.*

ANNUAL REPORTS.

ANNUAL REPORT OF THE BOARD OF GOVERNMENT FOR THE YEAR 1917–1918.

BOSTON, MASS., March 20, 1918.

To the Boston Society of Civil Engineers:

Pursuant to the requirements of the Constitution, the Board of Government presents its report for the year ending March 20, 1918.

The total membership of the Society a year ago was 966, of whom 846 were members, 77 juniors, 5 honorary members, 30 associates, and 8 were members of the Sanitary Section only.

The total loss in membership during the year has been 75, of whom 35 resigned, 29 forfeited membership on account of non-payment of dues, and 11 have died.

There has been added to the Society during the year, by election, a total of 26 members in all grades; 8 juniors, 1 associate and 1 member of the Sanitary Section have been transferred to the grade of member. Six applicants have been elected but have not completed their membership.

The following past presidents have been made honorary members during the year: John R. Freeman, George F. Swain, Ira N. Hollis and Howard A. Carson.

The present membership of the Society consists of 8 honorary members, 813 members, 64 juniors, 26 associates and 6 who are of the Sanitary Section only, making a total membership of 917.

The loss by death during the year has been 11. The record is as follows:

Otis F. Clapp, died March 3, 1917.
Joseph P. Davis, died March 31, 1917.
Albert S. Glover, died April 23, 1917.
Franklin B. Locke, died May 11, 1917.
Stanley A. Miller, died May 13, 1917.
Frank A. Pierce, died August 7, 1917.
William S. Johnson, died October 27, 1917.
Henry A. Herrick, died December 14, 1917.
Chauncey D. Bryant, died January 5, 1918.
Charles W. Gay, died February 1, 1918.
Thomas Aspinwall, died March 2, 1918.

In the death of Mr. Bryant, the Society suffers its first loss of a member who died in the war service of his country.

Under authority of By-Law 8, the Board of Government has remitted the dues of 21 members of the Society, of which number 14 are members who are now in war service and whose dues had not been paid at close of Society year.

Thirteen meetings have been held during the year, ten regular and three special meetings. The average attendance at these meetings was 134+, the largest being 360 and the smallest 27.

The following papers and addresses have been given:

March 21, 1917. — Address of Retiring President Richard A. Hale. Address of Mr. Frank M. Williams, state engineer of New York, on "The New York Barge Canal and Terminal Connections." (Illustrated.)

April 11, 1917. — (Special) Military Night. Addresses on the following topics: By George C. Whipple, "The Engineering Society in War Times"; by Lieut.-Col. W. P. Chamberlain, "Military Sanitation" (illustrated); by Capt. F. B. Downing, "Organization and Duties of Engineer Troops" (illustrated); by Capt. J. F. Osborn, "Engineering Instruction now being Given by the First Corps Cadets and the Formation of a New Engineer Regiment" (illustrated).

April 18, 1917. — Charles R. Gow, "The History and Present Status of the Concrete Pile Industry." (Illustrated.)

May 16, 1917. — Lieut. George D. Murray, "The Problems of Aviation as Applied to the Navy" (illustrated). Greely S. Curtis, "Various

Forms of Air Planes" (illustrated). Prof. Edwin B. Wilson, "Theory of the Aeroplane." Clifford L. Webster, "Experiences in Aerial Navigation."

September 19, 1917. — Frank A. Barbour, "Cantonment Construction Work at Camp Devens" (illustrated). Addresses on Cantonment Work by Capt. Edward Canfield, Jr., Frank Rogers, Maj. Glenn I. Jones and Leonard Metcalf.

October 17, 1917. — Henry I. Harriman, "Water Powers of New England." (Illustrated.)

November 21, 1917. — George C. Whipple, "Russia — An Opportunity for American Engineers."

December 19, 1917. — Charles T. Main, "Foundations of New Technology Buildings" (illustrated). Sanford E. Thompson, "Theoretical Design of the Structures of the New Technology Buildings" (illustrated).

January 11, 1918. (Special) John R. Freeman, "The Experiences of an Engineer in the Far East." (Illustrated.)

January 23, 1918. — Frank B. Walker, "The Engineering Features in Connection with Loading and Hauling Iron Ore from Mesabi Range to Lake Docks." (Illustrated.)

February 20, 1918. — Thomas C. Atwood, "The Submarine Menace and the Squantum Destroyer Plant." (Illustrated.)

February 27, 1918. — (Special) Clayton W. Mayers, "Economy in the Design of Concrete Buildings."

Three informal meetings have been held in the Society rooms during the year, at which talks on military matters were given as follows:

April 25, 1917. — Sanford E. Thompson, "Work being done on Store Houses for Supplies for the Army and Navy." Capt. H. S. Wonson, Supply Officer of the Eighth Massachusetts Infantry, "Work of the Commissary Department."

May 2, 1917. — Major Richard K. Hale, "Work of the Field Artillery." (Illustrated.)

May 9, 1917. — Major Edwin T. Cole, "The Making of War Maps."

The average attendance at these meetings was 36.

The Sanitary Section has held five meetings, with an average attendance of 33. The following papers have been presented at the meetings of the Section:

March 7, 1917. — George W. Fuller, "What shall be the Limitation in the Pollution of River Waters so that They may be Safely Purified by Modern Water Treatment Plants."

June 6, 1917. — Robert Spurr Weston, "Biological Self-Purification of Coweeset River, Brockton, Mass." (Illustrated.)

November 1, 1917. — Major Glenn I. Jones, "Precautions taken to Safeguard the Health of Workmen at Camp Devens."

December 5, 1917. — Stephen DeM. Gage and S. K. Nason, "Sanitary Conditions of Swimming Pools." (Illustrated.)

January 2, 1918. — J. Leslie Woodfall *et al.*, "Discussion on Sewer Pipe Joints."

A Committee on Military Affairs was appointed early in the year, and its work has been of much value to the Society. It arranged a most interesting special meeting devoted to military matters and several informal meetings at which military topics were discussed, and recommended many valuable books

on military subjects which were purchased for the library. Its most important work, however, was raising a fund for the purchase of military equipment for the regiment of engineers enlisted here in Boston.

By an almost unanimous vote, by letter ballot canvassed June 13, 1917, the Society adopted a resolution endorsing the formation of a regiment of engineers by transformation and enlargement of the First Corps of Cadets, and pledging to it the support and assistance of the Society. To carry out this pledge the committee decided to raise, by voluntary contribution from members of the Society, a fund for the purchase of equipment for this regiment not customarily supplied by the War Department. As result of an appeal for subscriptions, a total of $2 200 was received from 195 members, and on August 27, 1917, this sum was turned over to George W. Bunnell, colonel of the 101st Regiment, U. S. Engineers. The sum of $26.58, received since last August, is now on deposit in the Old Colony Trust Company, to the credit of this fund.

Word has recently been received that the whole, or a part of this money, was used to purchase musical instruments for a band, and that this regiment now has the distinction of being the only American regiment of engineers which has a band attached to it.

The members of the Society have freely enlisted in the war service of their country, and at the date of this report there are recorded on the roll of honor of the Society 85 members who are in the war service, and a service banner has been hung in the Society rooms with the proper number of stars.

At the request of the Massachusetts Civil Service Commission, a special committee of the Society was appointed to consider the question of the classification of civil engineers under civil service rules, and to suggest such modifications and changes as would improve the service. This committee devoted much time to the work, and submitted a most valuable report, which was accepted by the board and forwarded to the Civil Service Commission.

The committee on matters of interest to engineers coming before the Massachusetts legislature has been continued and has done much valuable work during the year.

A committee was appointed early in the year to consider any matters of an engineering character which might appropriately be brought to the attention of the State Constitutional Convention. Several meetings of the committee were held, but no definite action was taken.

The committee appointed last year to collect data on the run-off in New England which are available for water-power purposes, was continued this year, and has gathered much valuable data which it is expected will be presented soon in a report to the Society.

The Board of Government has adopted the recommendation of the committee appointed to award the Desmond FitzGerald medal, and has voted not to make an award this year, as in its opinion none of the papers in extent and quality merits the award

At the May and June meetings a sum not exceeding five hundred dollars was appropriated from the income of the Permanent Fund for improvement

and furnishing of the Society rooms. Of this appropriation the sum of $394.08 has been expended for the purchase of the book shelves owned by the New England Water Works Association and abandoned when that association moved to its new room, and for the installation of a ventilation shaft with an electrically driven fan in the large front room. The change has made the room comfortable and quiet for small meetings. All of the meetings of the Sanitary Section have been held in this room during the past year.

By an amendment to the By-Laws, a change has been made in the method of nominating officers, which takes effect the coming year. The new by-law provides for a nominating committee of nine, six members to be elected by letter ballot to serve for a term of two years and the three latest Past Presidents not members of the Board of Government. A further change is made, by which only a single candidate is to be nominated for each office except Directors and members of the Nominating Committee, where two candidates are required to be nominated for each office.

The report of the Editor of the JOURNAL for the calendar year 1917 shows that a total of 787 pages were printed in the ten issues, at a net cost of $1 997.44, or $2.54 per page, as against $1 883.81, or $2.19 per page, in 1916.

The Society by its vote at the February meeting approved the suggestion of the Board in regard to remitting the unpaid dues of members in the war service, by appropriating sufficient money from the income of the Permanent Fund to meet the loss. The Board now recommends that dues for the ensuing year be abated to all members in the military or naval service of the United States; and that the Current Fund be reimbursed for the consequent loss of income by an appropriation from the income of the Permanent Fund.

There has been added to the Permanent Fund during the year $1 799.75. The present value of this fund is $41 687.92, and with the Edmund K. Turner Fund makes the total value of the permanent funds of the Society $42 711.04.

From the Treasurer's report it appears that the revenue for the year applicable to current expenses has been $8 958.40, while the amount expended has been $9 153.89, making an excess of expenditures over revenue of $195.49, which, deducted from the balance on hand at the beginning of the year, makes the total cash on hand in the current fund $377.84.

For the Board of Government,

GEORGE C. WHIPPLE, *President.*

REPORT OF THE TREASURER.

BOSTON, March 1, 1918.

To the Boston Society of Civil Engineers:

Your Treasurer presents the following report for the year 1917–1918:

Detailed data are contained in the appended tabular statements. Table 1 gives the receipts and expenditures for the year: Table 2, comparative balance sheets; and Table 3, investment of the Permanent Fund.

The revenue applicable to current expenses has been $8 958.40, being

$399.65 less than for the preceding year. The current expenses were $9 153.89. The amount of cash on hand is $377.84.

The JOURNAL has been published at a much less expense than last year, the amounts being $3 851.48 and $3 436.92 respectively.

There has been an increase in the Permanent Fund of $1 799.75 after transferring from the income $500 for furnishings and $120 for dues of members in the war.

The note of the Dallas Electric Company for $500 was paid, and $2 000 was invested in 3½% Liberty Bonds; otherwise our investments remain unchanged.

Respectfully submitted,

F. O. WHITNEY, *Treasurer.*

TABLE I. — RECEIPTS AND EXPENDITURES

CURRENT FUND.

Receipts.

Balance from March, 1917		$573.33
Members' dues		7 298.93
Members dues paid from income of Permanent Fund		120.00
Advertisements		1 284.00
Sales of JOURNALS		232.37
Library fines		7.72
Waste paper sold		4.38
Interest on bank balances		11.00
		$9 531.73

Expenditures.

JOURNAL		$3 436.92
Printing, stationery, postage and library supplies (net)		971.10
Rent (net)		1 770.00
Light		60.90
Salaries (except editor)		2 096.00
Reporting		50.00
Stereopticon		40.00
Books		49.56
Binding		115.95
Periodicals		57.75
Incidentals (net)		128.93
Insurance		35.44
Annual meeting and dinner		304.39
Sanitary Section, reporting	$18.00	
" Stereopticon	6.00	
" Incidentals	12.95	36.95
Cash on hand		377.84
		$9 531.73

PERMANENT FUND.

Receipts.

Cash on hand March, 1917	$866.02
Entrance fees	255.00
Contribution	100.00
Dallas Electric Company, note paid	500.00
Interest	1 764.80
Deficit, March, 1918	34.18
	$3 520.00

Paid Out.

Coöperative bank dues	$900.00
Liberty Bonds purchased	2 000.00
Transferred to furnishing fund	500.00
Transferred to members' dues	120.00
	$3 520.00

E. K. TURNER LIBRARY FUND.

Cash on hand March, 1917	$4.12
Interest on bond	50.00
	$54.12
Books purchased	$24.75
Cash on hand March, 1918	29.37
	$54.12
1 Bond Am. Tel. & Tel. Co., book value	$993.75
Cash	29.37
Total value of fund	$1 023.12

FURNISHING APPROPRIATION.

Received from interest on Permanent Fund	$500.00
Expended	$394.08
Cash on hand March, 1918	105.92
	$500.00

TABLE 2. — COMPARATIVE BALANCE SHEETS.

Assets.	March 17, 1915.	March 1, 1916.	March 1, 1917.	March 1, 1918.
Cash.	$1 267.73	$3 163.37	$1 443.47	$478.95
Bonds and notes.	29 191.75	30 366.25	33 318.75	34 835.00
Stock. . . .	1 950.00	1 950.00	1 950.00	1 950.00
Coöperative banks	3 212.65	4 190.96	4 747.15	5 930.85
Accounts Receivable (rents). .	145.83	. . . . .	. . . . .	. . . . .
Library. .	7 500.00	7 500.00	7 500.00	7 500.00
Furniture. .	1 950.49	2 405.11	2 405.11	2 405.11
	$45 218.45	$49 575.69	$51 364.48	$53 099.91
Liabilities:				
Permanent Fund	$34 582.13	$37 475.69	$39 888.17	$41 687.92
E. K. Turner Fund.	. . . . . .	1 000.00	997.87	1 023.12
Unexpended appropriations	613.52	. . . . . .	. . . . . .	105.92
Current funds. . .	451.31	1 194.89	573.33	377.84
Accounts Payable .	121.00	. . . . . .	. . . . .	. . . . .
Surplus. . . .	9 450.49	9 905.11	9 905.11	9 905.11
	$45 218.45	$49 575.69	$51 364.48	$53 099.91

TABLE 3. — INVESTMENT OF THE PERMANENT FUND, MARCH 1, 1918.

Bonds.	Par Value.	Actual Cost.	Value as Carried on Books.
American Tel. & Tel. Co. Col. Tr. 4%, 1929,	$3 000.00	$2 328.75	$2 737.50
Union Elec. Light & Power Co. 5%, 1932. .	2 000.00	2 050.00	2 050.00
Blackstone Valley Gas & Elec. Co. 5%, 1939,	2 000.00	1 995.00	1 995.00
Dayton Gas Co. 5%, 1930.	2 000.00	2 000.00	2 000.00
Milford & Uxbridge St. Ry. 7%, 1923	3 000.00	2 942.50	2 942.50
Railway & Light Securities Co. 5%, 1939.	3 000.00	3 000.00	3 000.00
Superior Light & Power Co. 4%, 1931.	4 000.00	3 347.50	3 347.50
Wheeling Electric Co. 5%, 1941	4 000.00	3 845.00	3 845.00
Economy Light & Power Co. 5%, 1956	1 000.00	990.00	990.00
Tampa Electric Co. 5%, 1933	2 000.00	2 000.00	2 000.00
Galveston Houston Elec. Ry. Co. 5%, 1954,	2 000.00	1 940.00	1 940.00
Northern Texas Elec. Co. 5%, 1940.	2 000.00	1 932.50	1 932.50
Chicago & Northwestern Ry. 5%, 1987	1 000.00	1 102.50	1 102.50
Vermont Power & Mfg. Co. 5%, 1928	1 000.00	965.00	965.00
Am. Tel. & Tel. Co. 5% 1946	1 000.00	993.75	993.75
United States Liberty Loan $3\frac{1}{2}$%, 1947	2 000.00	2 000.00	2 000.00
	$35 000.00	$33 432.50	$33 841.25
Stock.			
15 shares Am. Tel. & Tel. Co..	1 500.00	1 950.00	1 950.00
Total Securities	$36 500.00	$35 382.50	$35 791.25

Coöperative Banks.

25 shares Merchants Coöperative Bank, including interest to March	$1 884.35
25 shares Volunteer Coöperative Bank, including interest to January	2 162.70
25 shares Watertown Coöperative Bank, including interest to March	1 883.80
	$5 930.85
Total value of invested funds	$41 722.10
Cash deficit	34.18
Total value of Permanent Fund	$41 687.92

	Par Value.	Actual Cost.		
E. K. Turner Fund.				
Am. Tel. & Tel. Co. 5%, 1946	$1 000.00	$993.75	$993.75	
Cash on hand			29.37	
				1 023.12
				$42.711.04
Furnishing Appropriation.				
Cash on hand				105.92
				$42 816.96

We have examined the above report and found it correct.

Arthur W. Dean,
Clarence T. Fernald,
Auditing Committee of Directors of the Boston Society of Civil Engineers.

Report of the Secretary, 1917–18.

Boston, Mass., March 20, 1918.

S. Everett Tinkham, Secretary, *in account with the* Boston Society of Civil Engineers.

For cash received during the year ending March 20, 1918, as follows:

From entrance fees, new members and transfers:

16 members and associates	at $10 =	$160.00	
10 juniors	at 5 =	50.00	
8 juniors transferred to members	at 5 =	40.00	
1 member, Sanitary Section, transferred to member	at 5 =	5.00	
Total from entrance fees			$255.00

From annual dues for 1917–18, including dues from new members	$7 218.43	
From back dues	26.00	
From dues for 1918–19	54.50	
Total from dues		$7 298.93
From rents		1 300.00
From advertisements		1 284.00
From sale of JOURNALS, reprints and cuts		232.37
From sale of old papers		4.38
From unexpended balance of funds received for joint excursion of June 13, 1917		14.37
From N. E. Water Works Ass'n, for telephone service		9.44
From library fines		7.72
From contribution to building fund		100.00
Total		$10 506.21

The above amount has been paid to the Treasurer, whose receipts the Secretary holds.

We have examined the above report and found it correct.

ARTHUR W. DEAN,
CLARENCE T. FERNALD.
Auditing Committee of Directors of the Boston Society of Civil Engineers.

REPORT OF LIBRARY COMMITTEE, 1917–18.

BOSTON, MASS., March 20, 1918.

To the Boston Society of Civil Engineers:

The Library Committee submits the following report for the year 1917–18.

Since the last report 233 volumes bound in cloth and 524 bound in paper have been added to the library, making a total of 757 accessions.

The cloth-bound volumes in the library now number 9 410, and those bound in paper about 2 500.

During the year 266 books have been loaned to members, and fines amounting to $7.72 have been collected.

The binding of reports and current volumes of magazines has been continued as usual, with the exception of a number of volumes of the English periodicals, which are still incomplete, certain issues having been shipped on vessels that were torpedoed on the way over. Thus far the newsdealers have not been able to supply these issues, and they are exceedingly pessimistic as to the possibility of ever obtaining them. It may also be noted in passing that the subscription price of the English periodicals is no longer a

fixed amount, and that American dealers are accepting subscriptions to these publications only with the understanding that the price may increase at any time during the year.

The fact may interest you that the Société des Ingenieurs Civils de France is still publishing its "Memoires," although at longer intervals than before the war, and that only one copy has been lost in transportation since the war began. A new copy was promptly forwarded upon our making application to the Secretary.

Twenty-three volumes on engineering subjects have been purchased for Section 10, and four others — "State Sanitation," in two volumes, by Prof. George C. Whipple; "Business Law for Engineers," by Prof. C. Frank Allen; and "Navigation," by Prof. George L. Hosmer — have been presented to the library by their respective authors. The Society is indebted to Mr. Sanford E. Thompson for a copy of "A Treatise on Concrete, Plain and Reinforced," third edition, 1917, by Messrs. Sanford E. Thompson and Frederick W. Taylor; and a copy of "Street Railway Fares," by Messrs. Dugald C. Jackson and David J. McGrath, has recently been received from Professor Jackson, "with the compliments of the Institute." Of the twenty-three books purchased for Section 10, eighteen were on military engineering and allied subjects.

A list of references on military subjects, begun in a small way at the time of the military meetings last spring, is being kept up, the references posted at that time on the bulletin board having been transferred to cards and other references added. Books on military subjects are indexed in this list as well as in the regular card catalogue.

Miscellaneous contributions of books and pamphlets have been received from the respective offices of Mr. Andrew D. Fuller and Mr. E. W. Bowditch. Early in the year a large collection of pamphlets, consisting chiefly of water reports of cities and towns, was turned over to the Society by the New England Water Works Association. While the greater part of these proved to be duplicates of reports already on the shelves, the collection yielded quite a number of those needed for the completion of the Society's files.

The increasing number of municipal reports obtained from various sources, that could not be accommodated in Section 3 under the former arrangement, have made it necessary to enlarge this section, which work is now in progress, the work of reclassifying, renumbering and recataloguing the section being carried on at the same time.

Respectfully submitted,

S. E. Tinkham,
Henry F. Bryant,
Frederic I. Winslow,
Committee on Library.

Report of the Executive Committee of the Sanitary Section.

Boston, Mass., March 5, 1918.

To the Sanitary Section, Boston Society of Civil Engineers:

During the past year five meetings of the Section have been held, as follows:

March 7, 1917. — Annual meeting. In addition to reports of the various committees, Mr. Geo. W. Fuller talked on the question "What shall be the Limitation in the Pollution of Rain Waters so that they may be Safely Purified by Modern Water Treatment Plants." Forty-five present.

June 6. — Illustrated talk by Robert Spurr Weston, on "Biological Self-Purification of Coweeset River, Brockton, Mass." Twenty-two present.

November 1. — Talk by Major Glenn I. Jones, on "Precautions taken to Safeguard the Health of Workmen at Camp Devens." Thirty-seven present.

December 5. — Illustrated talk on "Sanitary Conditions of Swimming Pools," by Stephen DeM. Gage and S. K. Nason. Forty-five present.

January 2, 1918. — Discussion on "Subject of Sewer Pipe Joints," by J. Leslie Woodfall *et al.* Eighteen present. This meeting reported in the February Journal.

An effort has been made this year to draw out a greater number of discussions at the meetings. We believe that much more can be done along this line than has thus far been accomplished, and that the results, if successful, will be of considerable benefit.

The meetings of the Section, as held in the Library, are less formal than when held in a larger room; and there is a greater tendency toward sociability, a feature which should be cultivated to an increased extent.

The ventilator installed during the past year has proven entirely satisfactory, thereby remedying one cause of discomfort. It is hoped that the difficulties with the projection screen can be overcome with equal success.

Three new members have been enrolled during the year, making the total membership 176.

Henry A. Varney, *Acting Clerk.*

Report of the Committee on Social Activities.

Boston, Mass., March 20, 1918.

To the Boston Society of Civil Engineers:

There were included in the activities of the Society during the past year three excursions. The principal work of this committee has been to arouse an interest in these events and to assist in the details necessary for the comfort of those attending and for the success of the excursions.

The Field Day of the New England Water Works Association and the Boston Society of Civil Engineers was held at Norumbega Park, June 17, 1917. The program included a ball game between the two societies, dinner at the Park restaurant, meetings of the societies after the dinner, and the regular attractions of the park. The attendance was 151, and there were

many ladies among the guests. The Boston Society won the ball game, the score being 20 to 4.

On December 19 there was an excursion to the Massachusetts Institute of Technology. Members and their guests were conducted by guides through the buildings, all assembling at the Hydraulic Laboratory in time for its inspection before dinner. Dinner was served at the Cafeteria, where 109 were seated. The regular meeting was held in the large lecture hall in the evening.

One hundred twenty-six members and guests visited the Squantum Destroyer Plant on February 20, 1918. Special cars from the Dudley Street Station were at the service of those in attendance, who were conducted over the plant in groups, by guides.

Respectfully submitted,

David A. Ambrose,
Chairman Committee on Social Activities.

Report of Committee on Run-Off.

Boston, March 20, 1918.

To the Boston Society of Civil Engineers:

The Committee on Run-Off, appointed December 20, 1916, has met eleven times, usually on the dates of Society meetings. It has discussed a number of questions affecting the accuracy of run-off measurements, particularly the following: Winter ratings; methods of measurement, and calendar year *versus* climatic year. The following subjects have also been given some attention, and it is hoped to discuss them more or less fully in the final report of the committee: Gage height observations; character of river; slope measurements; measurements at weirs and dams; velocity measurements; rating of current meters; current meter type characteristics; flood measurements; artificial control of flow (regulation); office method of computing and presenting data; relations of rainfall and run-off; length of records and effect on comparisons and analysis; use of snowfall data; evaporation, and New England precipitation.

The committee has found the amount of material so great that it can only report progress at the present time, and ask to be continued.

The value of the committee's work can be very much increased if some means can be found to reach other members of the Society who are interested in the same questions which the committee is studying. It is therefore requested that such members submit to the committee any discussions or suggestions which might help in this study.

At the December meeting of the Committee on Run-Off, the question of publishing run-off records by the calendar year instead of the climatic year was discussed, and a subcommittee was appointed with a twofold object:

First. To obtain the reasons why the Geological Survey changed from the calendar year to the climatic year.

Second. To find which method is preferred by the hydraulic engineers of New England.

In regard to the first object, the following letter, which was received from Mr. N. C. Grover, chief hydraulic engineer of the water resources branch of the U. S. Geological Survey, will explain itself.

" The reasons for this action on the part of the Survey may be grouped under two heads: First, the preparation of the data for publication; and second, the use of the data.

"*First:* It has been found to be in the interest of economy and accuracy to compute and prepare for publication the stream-flow data for the winter season as a whole. A break at the end of the calendar year leads to inconsistencies and inaccuracies of the most glaring type, as illustrated by the old records where the data were broken on December 31. These inaccuracies are largely avoided by the use of the climatic year and the computation at one time of the data for the whole period of ice.

"*Second:* In many sections of the country, and especially in those sections where irrigation is practiced, the use of the data is best served by its division between the season of use and the season of replenishment. Of course, if the data are published on any other basis, they may be assembled by the user on the basis of a climatic year adapted to the particular region in which he is interested. However, for most portions of the United States the year beginning October 1 seems to be adapted to the requirements."

In regard to the second object, each member of this committee was communicated with and requested to furnish a list of names of hydraulic engineers from whom he thought information should be obtained. A circular letter was sent to each one of the engineers indicated. About 36 replies were received. Of those, 31 could be used; 17 preferred the calendar year, 10 preferred the climatic year, 2 had no preference, and 2 felt that neither the climatic nor the calendar year gave a proper division.

The committee suffered a serious loss when Lieutenant Pierce was called into active military service. His assistant, Mr. H. W. Fear, has been acting as secretary of the committee since his departure, and his successor as engineer of this district for the Geological Survey, Mr. O. W. Hartwell, is acting with the committee.

Respectfully submitted for the committee,

Arthur T. Safford, *Chairman.*

Arthur T. Safford, *Chairman,*
Charles H. Pierce, *Secretary,*
Harold S. Boardman,
X. Henry Goodnough,
Richard A. Hale,
George E. Russell,
Charles W. Sherman,
Herbert A. Moody,
W. Frank Uhl,
Joseph F. Wilber,
Dana M. Wood,
Committee on Run-Off.

Report of the Editor.

To the Board of Government of the Boston Society of Civil Engineers:

Gentlemen, — The following is the Editor's report for the calendar year 1917. The customary 10 issues, of 1 250 copies each, comprising 24 papers and 7 memoirs of deceased members, have been published.

The total number of pages used was 787, and the net cost $1 997.44, or $2.54 per page, as against $1 883.81 or $2.19 per page in 1916.

The greater part of this higher apparent cost in 1917 is explained by the fact that the credit for advertisements is only for cash actually received, and does not include charges for some advertisements obtained in the latter part of the year. Actually, the amount of advertising carried at the end of the year was slightly greater than at the beginning of the year, and the charges against advertisers was about the same in both years.

Early in the year the President expressed some hope that the cost of the Journal might be reduced by a material increase in the number of advertisements. This result has not been realized, although in spite of a considerable number of withdrawals the amount of space carried, as just stated, has been maintained.

The Editor has done a considerable amount of work along these lines, and a large number of firms have been canvassed. Only in special cases has much encouragement been received. When the published papers have a direct appeal to a certain class of advertisers, interest can sometimes be aroused. Both the paper on Concrete Piles and the lecture on Camp Devens were the direct means of obtaining advertisements.

In a strictly professional journal, however, relations of this kind are of course only incidental, and cannot be developed for the sole purpose of increasing advertisements.

A considerable saving is possible by keeping the number of illustrations within moderate limits. At the present time, one full page half-tone costs about five dollars. It might also be desirable to discontinue the practice of making few reprints for authors, at a saving of some $150 per year.

A considerable saving in 1917 has been made possible by the coöperation of authors who have met the expense of a part or all of the illustrations in their papers, because they desired to secure the plates for other uses.

The appended table gives the details of costs and pages printed.

Respectfully submitted,

W. L. Butcher, *Editor.*

1917 Journal.

Month.	Pages of Papers.	Pages of Proc.	Pages of Index.	Pages of Adv.	No. of Inserts	No. of Cuts	Cost of Papers, Proc. and Index.*	Cost of Cuts.	Cost of Advts.	Cost of Reprints.	Cost of Postage, Wrapping and Mailing.	Cost of Editing.	Cost of Incidentals.	Cost of Copyright.
Jan.	65	13		16¼		23	$246.39	$31.85	$16.31	$29.50	$21.65		$3.26	$10.00
Feb.	36	14		16⅛		4	170.56	5.70	21.05	14.57	17.35		1.07	
Mar.	42	16		16		7	184.29	17.50	15.80	16.07	16.56		0.96	
Apr.	63	30		16		43	283.95	90.46	15.80	34.00	24.81		0.23	
May	36	14		16⅛		11	161.82	29.00	21.75	20.50	17.69			
June	22	12		16⅛			134.45		16.90	22.50	24.10			
Sept.	32	14		16⅓		1	170.50	4.17	21.48	21.00	20.97			
Oct.	46	12		16⅓		9	193.24	14.72	20.75	18.50	18.73			
Nov.	54	10		17⅝		25	233.85	80.10	27.65		19.19			
Dec.	54	12	10	16⅝		1	236.85	3.20	18.80	36.00	30.58			
Total	450	147	10	163½†		124	$2 015.90	$276.70	$196.20	$212.64	$211.63	$450.00	$5.52	$10.00

Total gross cost . . .		$3 378.68
Subscriptions . .	$34.68	
Sale of Journals . .	32.00	
Sale of reprints	23.63	
Author's payments for illustrations	176.93	
Receipts from advertisements .	1 114.00	
		1 381.24
Net cost .		$1 997.44

* Including stock for advertising pages.
† One hundred eighty pages used; not set solid.

APPLICATIONS FOR MEMBERSHIP.

[April 12, 1918.]

The By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of twenty (20) days from the date given.

Gauthier, Almon Isaac, Groton, Mass. (Age 30, b. Cornwall, Ont.) Graduate of Cornwall High School, regular three-year course and two-year college preparatory course. From September, 1906, to May, 1907, rodman with Locks and Canals Co., Lowell, Mass.; from June to December, 1907, rodman with B. M. R. R., Boston; from April to December, 1908, rodman on sewer and water works and transitman on street work with City of Lowell, Mass.; from April, 1909, to June, 1917, with B. & M. R. R., serving as rodman, transitman and assistant engineer on building construction, grade crossing elimination, etc., until October, 1911; from October, 1911, to June, 1914, as division foreman of bridges and buildings, W. N. & P. Division, Nashua, N. H.; from July, 1914, to January, 1915, as general foreman in charge of maintenance of bridges and buildings, Terminal Division, Boston; and for remainder of time as supervisor of bridges and buildings in charge of maintenance, Concord, N. H.; in June, 1917, enlisted in 14th Engineers (railway), and is now master engineer (senior grade), serving in France with that regiment. Refers to C. R. Chevalier, S. P. Coffin, A. B. Corthell, J. J. Rourke and F. C. Shepherd.

Haley, Frederic William, Haverhill, Mass. (Age 24, b. Haverhill, Mass.) From May, 1912, to April, 1916, with J. T. Desmond, C.E., Haverhill; is now assistant engineer with F. A. Barbour, in whose employ he has

been since April, 1916. Refers to F. A. Barbour, H. H. Chase, B. R. Felton, L. C. Lawton, J. E. Palmer and R. D. Hood.

STEWARD, HARRY MATTHEW, Medford, Mass. (Age 45, b. Skowhegan, Me.) Graduate of Lynn, Mass., Classical High School, 1892, course including special work in mathematics and surveying during last two years; studied civil and bridge engineering with International Correspondence School. From August, 1892, to 1899, rodman, transitman and assistant engineer with B. & M. R. R., engineering department; early in 1899 was transferred to maintenance of way department as assistant to road master of Southern Division, and on March 1, 1901, was appointed assistant road master in charge of Central Massachusetts branch of Southern Division, B. &. M. R. R.; from October, 1903, to date, with Boston Elevated Railway Co., having served as road master of rapid transit lines until March 1, 1912, when he was appointed chief engineer of maintenance of way department, which position he now holds; since February 1, 1918, all of the engineering of the company has been under his direction. Refers to J. E. Carty, F. H. Fay, C. T. Fernald, H. W. Hayes, H. C. Hartwell, F. W. Hodgdon, L. C. Lawton, A. L. Plimpton, J. H. Rourke, L. K. Rourke, J. P. Snow, J. H. Sullivan, G. F. Swain and S. E. Tinkham.

ROLL OF HONOR.*

ATWOOD, JOSHUA. Captain, Infantry, National Army, Headquarters Northeastern Dept., Boston, Mass.

BABBITT, JOHN H. 2d Lieutenant, C. A. C.

BALCH, WILLIAM H. Captain, E. O. R. C., Am. Ex. Force, France.

BEARD, CORNELIUS. 1st Lieutenant, Company A, 101st Engrs., Am. Ex. Force, France.

BRESTH, ALEXANDER.

BROWN, H. WHITTEMORE. 2d Lieutenant, E. O. R. C., 301st Engrs., Camp Devens, Mass.

BROWN, WILLIAM AUGUSTINE. Div. 4, Sec. 3, U. S. Naval Training Station, Bumkin Island, Mass.

† BRYANT, CHAUNCEY D. 1st-class Private, 101st Engrs., Am. Ex. Force.

BUNKER, PAGE S. Major, Ordnance Dept., U. S. N. A., Augusta Arsenal, Augusta, Ga.

BURLEIGH, WILLARD G. Corporal, Company E, 25th Engrs., Camp Devens, Mass.

BUSSEY, BYRON C. 2d Lieutenant, E. O. R. C., Officers' Training Camp, Washington, D. C.

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* This list is made up from replies to a circular sent out to members of the Society, and from various other sources. That future lists may be more accurate and complete, members are requested to call the attention of the Secretary to any inaccuracies or omissions.

† Died in France.

CLAPP, WILFRED A. Q. M. C.

CLARKSON, EDWARD H., Jr. Sanitary Engineer, American Field Ambulance.

COBURN, WILLIAM H. 1st Lieutenant, Field Supply Section, Gas Defense Service, New Interior Bldg., Washington, D. C.

CRAIGUE, JOSEPH S. Captain, Engrs., U. S. R., Am. Ex. Force, France.

CROSS, RALPH U. 1st-class Sergeant, Q. M. C., U. S. A., Headquarters Northeastern Dept., Boston, Mass.

CURTIS, GREELY S. Lieutenant (j. g.), Naval Militia, Mass.

DASHPER, FREDERICK C. With British Army.

DAVIS, HAROLD F. Supply Sergeant, 6th Reg't, Company A, Mass. Infantry, Am. Ex. Force, France.

DELANO, RAY O. Sergeant, Company B, 301st Engrs., Camp Devens, Mass.

DEMERRITT, ROBERT E. 2d Lieutenant, C. A. C., U. S. A., Fort Monroe, Va.

DEMING, GUY S. 1st Lieutenant, Signal Corps, Construction Div., Aviation Section, 49 South Maple Avenue, East Orange, N. J.

DRUMMOND, WILLIAM W. Captain, Engrs., U. S. R., Camp Lee, Va.

DURHAM, HENRY W. Captain, Engrs., R. C., 20th Engrs., Camp American Univ., Washington, D. C.

EDDY, HARRISON P., Jr. Assistant Naval Constructor, U. S. N. R. F., U. S. Navy Yard, Norfolk, Va.

ELKINS, CLAYTON R. Lieutenant, Public Works Dept., Navy Yard, Norfolk, Va.

ELLSWORTH, SAMUEL M. Company I, 3d Officers' Training Camp, Camp Upton, Long Island, N. Y.

ENEBUSKE, CARL C. 55th C. A. C.

FERNALD, GORDON H. 1st Lieutenant, E. O. R. C., 304th Engrs., Accotuik, Va.

FOOTE, FRANCIS C. Lieutenant, 303d Engrs., E. O. R. C.

FRENCH, HEYWOOD S. Major, Q. M. C., National Army, 2521 University Place, Washington, D. C.

GERRISH, HERBERT T. 1st Lieutenant, Engr. R. C., E. R. O. T. C., Camp Lee, Va.

GIBLIN, JOHN F. A. 1st Lieutenant, 101st Engrs., Am. Ex. Force, France.

GOW, CHARLES R. Major, Q. M. C., National Army.

GUNBY, FRANK M. Lieutenant Colonel, Cantonment Div., Q. M. C., U. S. R., 1156 15th Street, Washington, D. C.

GUPPY, BENJAMIN W. Major, 14th Engrs., Am. Ex. Force, France.

HALE, RICHARD K. Lieutenant-Colonel, 101st Field Artillery, Am. Ex. Force, France.

HANF, FRANK S. 2d Lieutenant, Engrs., U. S. R., 2d Battalion, 2d U. S. Engrs., Am. Ex. Force, France.

HANNAH, THOMAS E. 1st Lieutenant, C. A. C., Fort Monroe, Va.

HARTY, JOHN J., Jr. Captain, Ordnance Dept., U. S. R., Springfield Armory, Springfield, Mass.

HASTIE, FRANK B. 2d Lieut., Engr. Corps, U. S. A.

HOBSON, GEORGE F. Captain 305th Engrs., Camp Lee, Petersburg, Va.

HUBBARD, CARL P. Sergeant, Company D, 11th Engrs. (Ry.), Am. Ex. Force, France.

KENDALL, THEODORE R. 1st Lieut., Sanitary Corps, National Army.

KIMBALL, HERBERT S. Captain, Ordnance Dept. (Technical Section), Officers' Reserve Corps.

LEONARD, JOSEPH F. A. 2d Lieutenant, Engrs, U. S. R., Officer in Charge, Engr. Sub-Depot; Commanding Engr., Depot Detachment 421, Camp Wadsworth, Spartanburg, S. C.

LOHMEYER, WILLIAM, Jr. 2d Lieutenant, Corps of Engrs., U. S. A., Barrack 47, McClellan Avenue, Fort Leavenworth, Kan.

LOUD, RALPH W. Private, National Army.

LUTHER, HOWARD B. Lieutenant (j. g.), U. S. N. R. F., 1707 H Street, N. W., Washington, D. C.

MATTSON, WILLIAM R. 1st Lieutenant, Company E, 101st Engrs., Am. Ex. Force, France.

MONAGHAN, JAMES F. Captain, Ord. R. C., U. S. A., 1330 F Street N. W., Washington, D. C.

MOORE, LEWIS E. Captain, E. O. R. C., Am. Ex. Force, France.

NASH, PHILIP C. 1st Lieutenant, E. O. R. C., U. S. A., Washington Barracks, Washington, D. C.

NOLAN, CONRAD. Corporal, Battery D, 301st Field Artillery, Camp Devens, Mass.

OBER, ARTHUR J. Major, E. O. R. C.

OSBORN, JOHN F. Captain, Company B, 101st Engrs., Am. Ex. Force, France.

PIERCE, CHARLES H. 1st Lieutenant, Engrs., U. S. R., 7th Company, Engr. Reserve Officers' Training Camp, Camp Lee, Va.

RAND, ROBERT. Lieutenant (j. g.), U. S. N. R. F., Communication Office, Bldg. 24, Navy Yard, Boston, Mass.

REED, LESLIE P. 2d Lieutenant, U. S. Signal Reserve Corps, Engr. Section, Room 356, Union Station, Washington, D. C.

RICHARDSON, EDWARD B. Captain, Battery A, 101st Field Artillery, Am. Ex. Force, France.

RICHMOND, CARL G. 1st Lieutenant, 602d Engrs., Camp A. A. Humphreys, Va.

SAVILLE, THORNDIKE. 1st Lieutenant, Signal Corps, U. S. A., Construction of Water Supply and Sewerage Systems, Supply Div., Langley Field, Hampton, Va.

SAWYER, GEORGE S. Sergeant, Company A, 504th Engrs. Battalion, Camp Devens, Mass.

SHAW, ARTHUR L. Captain, Engr. R. C., 301st Engrs., Camp Devens, Mass.

SMITH, WILLIAM H. Lieutenant, Asst. C. E., C. E. C., U. S. N.

SNOW, LESLIE W. 1st Lieutenant, Gun Div., Office of Chief of Ordnance, 1330 F Street, Washington, D. C.

SOUTAR, GEORGE P. Private, 17th Company, 151st Depot Brigade, on detached service studying meteorology at U. S. Weather Bureau, Boston, Mass.

SPEAR, WALTER E. Major, Q. M. R. C., Camp Upton, Long Island, N. Y.

STENBERG, THORNTON R. 2d Lieutenant, 301st Infantry, on detached service at School of Military Aeronautics, University of Texas, Austin, Tex.

STROUT, HENRY E., Jr. 1st Lieutenant, C. E., U. S. A., 319th Engrs., Camp Fremont, Cal.

THOMPSON, SANFORD E. Major, Progress Section, Office of Chief of Ordnance, Washington, D. C.

TOSI, JOSEPH A. Private, Company 2, 3d Officers' Training Camp, Camp Devens, Mass.

TUCKER, HERMAN F. Ensign, U. S. N. R. F., Seattle, Wash.

WADE, CLIFFORD L. 1st Lieutenant, E. O. R. C., care U. S. Geological Survey, Washington, D. C.

WADSWORTH, GEORGE R. Major, Aviation Section Signal Corps, U. S. A., Chief Engr., Naval Aircraft Factory, Navy Yard, Philadelphia, Pa.

WARING, CHARLES T. Major, Supply Div., Signal Corps, Langley Field, Hampton, Va.

WEBB, DEWITT C. Lieutenant Commander, Public Works Office, U. S. Navy Yard, Philadelphia, Pa.

WELLS, EDWARD P. Cadet, U. S. A. School of Military Aeronautics, Ithaca, N. Y.

WENTWORTH, JOHN P. Captain, Sanitary Corps, National Army, Div. Headquarters, Camp Lee, Va.

WESTON, ARTHUR D. Lieutenant, 26th Engrs., Camp Dix, N. J.

WHITMAN, RALPH, Lieutenant Commander, U. S. Navy, care U. S. Military Gov't, San Domingo, R. D., via Postmaster, N. Y.

WHITNEY, ORVILLE J. Major, Auto Aircraft Machine Gun Battalion, Camp Wadsworth, N. Y.

WHITNEY, RALPH E. 1st Lieutenant, Sanitary Corps, National Army, Surgeon General's Office, Washington, D. C.

WIGGIN, THOMAS H. Captain, E. O. R. C., Am. Ex. Force, France.

WOOD, FREDERIC J. Major, Engrs., U. S. R., Curtis Bay Ordnance Depot, South Baltimore, Md.

WOOD, LEONARD P. Captain, E. O. R. C., Am. Ex. Force, France.

WORCESTER, ROBERT J. H. 1st Lieutenant, Inf. R. C., Company 12, 3d Battalion, Depot Brigade, Camp Devens, Mass.

LIST OF MEMBERS.

ADDITIONS.

KILLION, LOUIS J. . . . . 45 Winthrop St., Roxbury, Mass.
SAUER, FRED E., Jr. . . . . 50 Norwood St., Everett, Mass.

CHANGES OF ADDRESS.

Atwood, Thomas C. .... U. S. Navy Dept., Atlantic, Mass.
Blanchard, Arthur H. Broadway and 117th St., New York City, N. Y.
Buckley, William J. .... 65 Winter St., Montello, Mass.
Clark, Charles S. .... Room 754, 141 Milk St., Boston, Mass.
Connolly, S. John .... 201 Devonshire St., Boston, Mass.
Curtis, Ralph E. .... 15 Allen St., West Roxbury, Mass.
Eberhard, Walter C. .... 76 Morris St., Dover, N. J.
Ferguson, John N.,
Mass. Comm. on Waterways and Public Lands, Dry Dock, Boston, Mass.
Forbes, Fred B. .... 541 State House, Boston, Mass.
Ford, Arthur L. .... 12 Marshall St., Malden, Mass.
Fuller, Andrew D. .... 22 Kent St., Somerville, Mass.
Fuller, Frank L. .... 201 Washington St., Wellesley, Mass.
Grover, Nathan C. .... 1442 Belmont St. N. W., Washington, D. C.
Harkness, Arthur F. .... 541 State House, Boston, Mass.
Horne, Harold W. .... Miami Conservancy District, Dayton, Ohio
Hunter, Harry G. 615 New Birks Bldg., Montreal, Canada
Hutchison, Richard .... 49 Federal St., Boston, Mass.
Manley, Henry, Jr. .... 819 Gravesend Ave., Brooklyn, N. Y.
Morrill, Frank P.,
13 Rosewood Terrace, Tompkinsville, Staten Island, N. Y.
Morrison, John W. .... Room 203, 60 Congress St., Boston, Mass.
Nelson, William .... 41 Magazine St., Cambridge, Mass.
O'Brien, James A. .... City Hall, Chelsea, Mass.
Pike, Waldo F.,
care Fay, Spofford & Thorndike, 308 Boylston St., Boston, Mass.
Pratt, Daniel W. .... 11 Willow St., Winchester, Mass.
Proctor, Fred W. .... Hoosac St., North Adams, Mass.
Rockwood, Edward F. .... 147 Milk St., Boston, Mass.
Savage, John Dana .... 1864 Northampton St., Holyoke, Mass.
Sears, Calvin C. .... 3 Bryan Ave., Branford, Conn.
Smith, Sidney .... 5347 Baltimore Ave., Philadelphia, Pa.
Stearns, Ralph H. .... 1 Ashburton Place, Boston, Mass.
Sutton, David .... 15 Ashmont Road, Waban, Mass.
Thomas, John F., Care Charles T. Main, 201 Devonshire St., Boston, Mass.
Tosi, Joseph A., Care Charles A. Tosi, 152 Franklin St., New York, N. Y.
Van der Pyl, Edward .... 9 Clifton St., Worcester, Mass.
Walker, Frank B. .... 245 State St., Boston, Mass.
Warren, Henry E. .... 149 Meridian St., East Boston, Mass.

DEATHS.

Aspinwall, Thomas .... March 2, 1918.

RESIGNATIONS.

(In effect March 20, 1918.)

Ackerson, Herbert N.
Burr, Thomas S.
Caldwell, Frederick A.
Davis, Leonard H.
Drowne, Henry B.
Durant, William B.
Foller, Samuel J.
Hall, Frank E.
Hoxie, Arthur E.
Kelley, Mark E.
Lanphear, Roy S.
Marvell, Edward I.
Mead, Royal L.
Morrill, Fred W.
Nash, S. Aubin.
Phillips, Henry A.
Sarle, O. Perry.
Saville, Caleb Mills
Skinner, Fenwick F.
Smith, Melvin B.
Stocker, Malcolm G.
Von Loesecke, Sidney S.
Whitney, Walter C.

EMPLOYMENT BUREAU.

The Board of Government maintains an employment bureau for the Society, to be a medium for securing positions for its members and applicants for membership, and also for furnishing employees to members and others desiring men capable of filling responsible positions.

At the Society room two lists are kept on file, one of *positions available* and the other of men *available*, giving in each case detailed information in relation thereto.

Men Available.

421. Age 49. Has had wide experience in heavy construction on tunnels, dams, canals, pipe lines and water works; would prefer position along these lines, although experience also covers sewers, pavements, highways and steel bridge erection. Would accept salary of $150 per month, with good opportunity for advancement.

LIBRARY NOTES.

Recent Additions to the Library.

U. S. Government Reports.

Annual Report of Director of Geological Survey for 1916–17.

Antimonial Silver-Lead Veins of Arabia District, Nevada. Adolph Knopf.

Borax in 1916. Charles G. Yale and Hoyt S. Gale.

Cement in 1916. Ernest F. Burchard.

Chemical Analyses of Igneous Rocks. Henry Stephens Washington.

Combustion of Coal and Design of Furnaces. Henry Kreisinger and others.

Compressibility of Natural Gas and Its Constituents, with Analyses of Natural Gas from Thirty-one Cities in United States. G. A. Burrell and I. W. Robertson.

Control of Hookworm Infection at Deep Gold Mines of Mother Lode, California. Dr. James G. Cumming and Joseph H. White.

Dunkleberg Mining District, Granite County, Montana. J. T. Pardee.

Effect of Low-Temperature Oxidation on Hydrogen in Coal and Change in Weight of Coal on Drying. S. H. Katz and H. C. Porter.

Five Ways of Saving Fuel in Heating Houses. Henry Kreisinger.

Fluorspar and Cryolite in 1916. Ernest F. Burchard.

Gold, Silver, Copper, Lead, and Zinc in Nevada in 1916. V. C. Heikes.

Gold, Silver, Copper, Lead, and Zinc in New Mexico and Texas in 1916. Charles W. Henderson.

Gold Placers of Tolovana District, Alaska. J. B. Mertie, Jr.

Louisiana Clays. George Charlton Matson.

Possibilities for Manganese Ore on Certain Undeveloped Tracts in Shenandoah Valley, Virginia. D. F. Hewett and others.

Stratigraphy in Southwestern Maine and Southeastern New Hampshire. Frank J. Katz.

Tin Resources of Kings Mountain District, North Carolina and South Carolina. Arthur Keith and D. B. Sterrett.

Vapor Pressures of Various Compounds at Low Temperatures. G. A. Burrell and I. W. Robertson.

Water-Supply Papers 406, 418, 424, 430, 434, 445.

State Reports.

Massachusetts. Proceedings of Fifth Annual City and Town Planning Conference of Massachusetts Planning Boards, 1917; Lowell Homestead Project.

Michigan. Annual Report of State Board of Health for 1914–15.

Ohio. Technical Reports of Miami Conservancy District as follows: Miami Valley and 1913 Flood, by Arthur E. Morgan; Theory of Hydraulic Jump and Backwater Curves, by Sherman M. Woodward, and Hydraulic Jump as Means of Dissipating Energy, by Ross M. Riegel and John C. Beebe; Storm Rainfall of Eastern United States, by Engineering Staff of District.

Municipal Reports.

Belmont, Mass. Annual Report of Water Commissioners for 1917.

Cambridge, Mass. Annual Report of Water Board for 1916–17.

Detroit, Mich. Annual Report of Water Commissioners for 1916–17.

Laconia, N. H. Annual Reports of Board of Public Works for 1917.

Melrose, Mass. Annual Report of Park Commissioners for 1917.

Northampton, Mass. Annual Report of Water Commissioners for 1917.

Plymouth, Mass. Annual Report of Water Commissioners for 1917.

Providence, R. I. Annual Reports of Water Supply Board for 1915–16 and for 1917.

Rutland, Vt. Annual Report for 1917.

Miscellaneous.

American Institute of Mining Engineers: Transactions for 1917, Vol. LVI.

American Society of Civil Engineers: Transactions for 1917, Vol. LXXXI.

Canada, Department of Interior: Catalogue of Stars for Latitude Observations on Dominion Lands Surveys.

Canada, Department of Mines: Production of Copper, Gold, Lead, Nickel, Silver, Zinc and Other Metals in Canada during 1916; Iron Ore Occurrences in Canada, Vol. II, with maps, by E. Lindeman and L. L. Bolton.

Cement-Gun Co., Inc.: Bulletins.

Diamond Power Specialty Co.: Diamond Soot Blowers for Water Tube Boilers.

Navigation. G. L. Hosmer. Gift of author.

LIBRARY COMMITTEE.

NEW ENGINEERING WORK.

(Under this head a brief description of new engineering work contemplated or under construction will be presented each month. Engineers and contractors are requested to send descriptions of their work to the Secretary, 715 Tremont Temple, Boston, before 1st of each month.)

Commonwealth of Massachusetts.—METROPOLITAN WATER AND SEWERAGE BOARD. — *Water Works.* — The new 3,000,000-gal. centrifugal pumping unit at the Arlington Pumping Station has been erected, and is nearly ready for operation.

METROPOLITAN PARK COMMISSION. — *Old Colony Parkway.* — Construction of a temporary bridge across the Neponset River between Boston and Quincy is in progress; also construction of double siphon for water and gas under new channel.

BOSTON TRANSIT COMMISSION. — Work is progressing on the Surface Station near Massachusetts Avenue for the transfer of passengers between surface and subway cars.

The following repaving in South Boston where the Dorchester Tunnel has been constructed will soon be begun:

Dorchester Avenue on a concrete base between West Second

Street and Old Colony Avenue, and between Humboldt Place and the southerly side of Andrew Square, and Boston Street on a gravel base from Andrew Square to the vicinity of Ralston Street.

New York, New Haven & Hartford R.R. Co. — *South Boston Cut Improvement.* — Enlargement of South Boston Cut to Boston Freight Terminal, to accommodate four tracks instead of two, and reconstruction of eleven overhead highway bridges, so as to span four tracks instead of two, progressing. Excavation by steam shovel has advanced from westerly end of cut into Broadway. Bridge abutments being constructed at West Sixth Street, West Fifth Street, Gold and Silver streets. Permanent pumping plant being constructed at Dorchester Avenue.

Vol. V APRIL, 1918 No. 4

BOSTON SOCIETY OF CIVIL ENGINEERS
FOUNDED 1848

PAPERS AND DISCUSSIONS

This Society is not responsible for any statement made or opinion expressed in its publications

ADDRESS AT THE ANNUAL MEETING.

By George C. Whipple, President Boston Society of Civil Engineers.

(March 20, 1918.)

The Engineer in the New Democracy.

In complying with the prescribed obligation of the retiring president to deliver a valedictory address, I cannot in these days of war speak of anything else than our own place in the great struggle and in what will come after. I have accordingly taken for my subject, *The Engineer as a Social Force in the New Democracy.*

The United States has been at war nearly a year. The victory is not yet won. But we are going to win it, — that much is certain. We are going to win the war because we believe the cause of liberty is worth fighting and dying for, and because we have men enough who are willing to fight and die. We are going to win because American resources directed by American engineers, when added to the forces of our allies, will turn the scale of military power in our favor. Victory will come; but what will come after the victory? The world will be made safe for democracy; but how is democracy to be made safe for the world?

It is hard to look ahead, these days, and very hard to see clearly, but never was foresight so much needed as now. En-

gineers, as a class, have been trained to look ahead. To draw a plan is to look ahead, — and the planners of our railroads, our water supplies, our power distribution plants have seldom failed to exercise good judgment in forecasting the future.

In recent years our forecasting has been largely on a mathematical basis, — it has been a quantitative problem; but now the problem is different. Unless signs fail there is going to be a social reconstruction of the world. In fact, this is now going on before our very eyes if we will but see. Ferrero said that when Rome fell the Romans at the time never knew that it was falling.

The engineer must therefore extend his thought far beyond his usual bounds, because the new problem is not physical and mathematical, but rather political and ethical. The engineer must join with the members of the other professions, and what is more important he must join with the workers themselves, in laying plans for the new democracy and the new social order which seems destined to come not only in Russia but in England and Germany, in America, and, we may well say, throughout the civilized world. Because of his experience in looking ahead, because of his position as an intermediary between owner and contractor, between capital and labor, because of his habit of doing things in large ways, the engineer seems destined to play an important part in the coming reconstruction. The engineer's prominence in the war will give him added opportunities after the war is over. To the victors belong the responsibilities, not the spoils.

It is hard to tell even in generalities what is going to happen, but some things seem reasonably certain. Autocracy is going to give way to democracy in all of the great countries of the world. This means that to a greater extent than ever before the political power will be in the hands of the working people, that persons of limited education will have more direct control than now of the policies and actions of their governments. The relations between capital and labor are going to change; the wage system will be modified and may even give way to some other system of payment based on the idea of profit sharing. The great fortunes and the great holdings of land are going to be subdivided. The government may control not only the

railroads, but other public utilities, as well as the basic resources of nature. We are going to live under new conditions, and, whatever our preconceived ideas, we must adapt ourselves to the new order. The changes will not come in a day, but they will come sooner than any of us would have predicted a year or two ago. Indeed, they have already begun.

Efficiency and Democracy. — Democracies, considered as nations, are inefficient. History tells us that. Yet we need not go back of the present war to see it. An army is more efficient than a mob; an organized nation is more efficient than one not well organized; industry and transportation organized under the large corporation plan are more efficient than under the small unit plan. Organization and efficiency seem to be inseparable terms.

Where efficiency exists, the ruling power is almost invariably at the top and its branches extend downwards, ever dividing as in the vagarious organization-charts which our bureaus of municipal research delight to draw. But what is meant by efficiency? Broadly speaking, it is doing much with little effort; it is getting out of a machine in one form the energy put into it in another form; it is making the most of the apparatus, the best use of time, accomplishing a result in the best way. In any measure of machine efficiency the thought is centered primarily on the result, secondarily on the power applied and the raw material consumed, lastly on the effect of the process on the machine itself. Under autocracy we see this idea illustrated in human society. The upper ruling power has a result in mind, — it may be benevolent or selfish, — the nation is organized to secure that result, all the units of the nation are required to work to that end, and the effect of the process on the constituent human units is regarded as a minor affair. The United States is temporarily and of necessity in this condition to-day. The object in view is to win the war; we are voluntarily organizing ourselves from the top down, to bring about this result; we are trying to make the most of our powers and resources; and we don't care what happens to any one of us.

But in times of peace conditions are different. Then the legitimate object of government is to provide conditions favor-

able for the life of each and every individual in the nation. The purpose of the nation is not ulterior, but interior. Efficiency takes on a new meaning. No longer is it a comparison between applied energy and material result, but a threefold comparison between process, machine and product, with the effect of the process on the machine as the controlling thought. In mechanics we have no single word to express this idea, although we do speak of the "life of the plant," of "friction," of "depreciation." In human society we have already some very old and very adequate words, — health, comfort, happiness and contentment of the people, — sometimes summed up in the word "welfare." In autocracy, efficiency means a comparison between work and result; in democracy, it should mean rather a comparison between work and welfare. Such relations might be called *beneficient*, to use an obsolete word with a somewhat new meaning, — a word not to be confounded with beneficent or benevolent, both of which contain the element of charity. *Beneficiency* is not that; it is efficiency plus humanity. In this country, as in most civilized countries, we have striven for efficiency, and it is partly for this reason that the laboring people claim that we are an economic autocracy. It is well known that the movement for efficiency has not been received in a friendly spirit by the laboring people. Why? Because they believe just this, — that efficiency considers the work and the product and leaves them out. Beneficiency would mean placing the product and the effect on the worker in equal regard. The world is demanding that this change be made.

The present war is expanding in a most remarkable and significant manner. At the beginning it was regarded as a contest of nations; then it was seen to be a contest between national autocracy and national democracy; now it is becoming something still broader, — a contest between social autocracy and social democracy the world over. We saw this first in Russia, and we viewed it with alarm; but when we see it spread over Austria and Germany we do not object, because it will tend to disintegrate our enemies. Do we realize that the same contest is going on in England and America? And when it comes, as come it will, how are we going to receive it? Our future

tranquillity depends much upon the answer. Are we going to hold to the old idea of efficiency, and make the product of the nation the object of our work, or are we going to take the new view of beneficiency and place the welfare of the worker on an equality with his product, bending our present organizations to that point of view, lest they be broken altogether?

I hate the German nation as exemplified by the Prussian autocracy, with what, I hope is a righteous hatred, and I am confident that Germany will be beaten and her present rulers blotted out; but I do not believe that a mere crushing of the German military power will bring peace to the earth. I believe that a readjustment of political and social conditions throughout the world is inevitable, and that peace and tranquillity will not come until these great questions are settled. We talk with disdain about the revolutionists of Russia, and the word "Bolshevic" has come to have a sinister meaning. But the ignorant, well-meaning Russian people are honestly seeking a way to build up a new democracy, social, political and religious, and we will do well to study their efforts. With their lack of knowledge and experience, with a dark background of brutal repression, they are making grievous work of it. We, with universal education, with more than a century of liberty and free government as a background, ought to do better. The Russians have the spirit but lack the education; we have the education, — do we lack the spirit?

Following the war the great problems of the day will be social problems, and the engineer must play his part in them. As the great exponent of efficiency, it will be one of his first tasks to alter the meaning of the term so that it will of necessity include a higher regard for the worker, — for his health, for his comfort and for his general welfare.

Conceptions of Democracy. — While we of America believe in democracy, there have been many able, honest, doubters among the world's great thinkers. If one wishes to appreciate this let him read Lecky's "Democracy and Liberty." In looking forward to a wider democracy, coextensive with civilization, it is important to consider what sort of democracy will be most beneficient. The first step in this study is to see in what

respects people are thinking and acting along wrong lines. Professor Swain summarized these admirably in his presidential address before the American Society of Civil Engineers, at Ottawa, in 1913 (Trans. Am. Soc. C. E., LXXVI, 1112–1147), and I cannot do better than repeat here some of the things which he then said.

First of all, "*There is a tendency to consider that all men are equal in all respects*," an idea so obviously untrue that it ought not to need refutation. Men and women are different from each other, and these differences must be recognized in a democracy. With equal rights before the law, with equal rights and as far as possible equal opportunities to develop, with equal rights to the great essentials of human welfare, with equal rights to be judged according to worth, it yet remains that there are differences in people which cannot and ought not to be blotted out, but which on the other hand ought to be made the basis of penalty and reward. The rewards should not be equal; the ten-talent man should receive more than the one-talent man. In some way or other, I cannot say how, a man's reward, whether it be for the work of his hands, his head or his heart, should bear a reasonable relation to what he contributes to the common good.

Second, "*There is a tendency to disregard authority, to consider that one man's opinion is as good as that of any other, — a condition which leads to intellectual arrogance, dogmatism and lawlessness.*" Superabundance of printed matter has encouraged this, while the headline habit has led to loose thinking, to the absorption of undigested fragments, and to the loss of the critical faculty. The daily newspaper is doing much to bring about intellectual equality in man; it raises the level of the uneducated by enabling him to learn about science and literature and affairs of state, while it lowers the level of the intelligent by feeding him on Buster Browns and Krazy Kats. In the daily press the opinion of the experienced man who really knows what he writes about is placed on the same level as that of the cub reporter who cares more for his story than for the truth.

Third, "*There is a disregard of experience, a tendency to consider any man good for any job.*" This is most glaring in the political world. We choose our executives by popular vote,

without regard to special experience or training; we even talk about training a city manager in a technical school. Do we not know that a well-ripened city engineer is the man best fitted to be a city manager, — that judgment comes only with experience? Why do reform governments so often fail? Because success depends not only upon honesty but upon knowledge and experience. Why do reactionary governments so often succeed? Because extravagance and corruption are not synonymous terms, and because the "old line" government is often beneficient rather than efficient, thereby getting better results from the employees. We must not lose sight of the fact, however, that corruption and extravagance too often go together, and that a beneficient government may become far too benevolent to its office holders, with efficiency left to take care of itself.

Fourth, "*There is a tendency to relax discipline.*" This was the first effect of the Russian revolution. The soldiers refused to obey or even to salute their officers. But we do not need to go to Russia for illustrations. We see it in our schools, in our homes, in our laws, in our social relations. Professor Swain says, "We are victims of an exaggerated humanity and a decay of discipline. We fail to recognize that a prescription often needed, instead of condoling, kind words, sympathy and self-sacrifice, is the prompt and energetic application of the toe of the boot to the lower end of the spinal column."

Fifth, "*There is a tendency to laud innovations, to discredit the old and exalt the new,*" — a tendency which springs perhaps from the rapid progress of science and inventions.

Sixth, increase of wealth has led to luxury, extravagance, ostentation and waste.

Seventh, increasing altruism is perhaps causing the survival of the unfit and hence a tendency to the deterioration of the race.

These seven accusations of democratic tendencies are worthy of most serious thought. Different people will accept them in varying proportions, but it must be admitted that there is truth in each one.

What, then, is democracy? It was never defined better than by Lincoln, — "A government of the people, by the people,

for the people." The United States lives by these words to-day. Are we about to apply the same formula to public utilities, to business, to industry? It looks so. The workers are demanding a share in the control of their work. They will get it, and I believe they ought to get it. But Lincoln's formula does not say that all men are equal, that we should disregard experience and authority, or that we should relax discipline and abolish organization, or that service should be unrewarded and neglect of duty go unpunished. It is just as important for the workers to study their Lincoln — our Great Labor President — as it is for the men who manage business to study what he said and did.

Work and Rewards. — The great contest will, as it always has, center around the problem of rewards. Few will deny that to-day rewards are disproportionate to service rendered the community in many of the walks of life. It has seemed to me that for many years the unskilled laborer, the common workman, has not received his fair share of the satisfactions of life. He has not been happy in his work, and if a man does not find happiness in his work he will not be contented, because a large part of every one's life is given up to work. The change from the outdoor life of the farm to the indoor life of the factory, the extreme subdivision of labor by which a man or a woman does but one thing in a most monotonous way is largely responsible. The mind cannot get satisfaction out of quantitative work, out of so-called efficient labor, even though the money in the pay envelope increases. One great problem, therefore, is to find a way to make hard, routine work less monotonous, more enjoyable, more healthful. We cannot, of course, get away from work or from hard work, if we try; there must also be self-sacrificing work. We can, however, improve working places with respect to hygienic and attractive conditions, and we can improve work with respect to hours and rest periods and to permanency of occupation. But we must also have efficient work, and this means better planning of details.

To establish a uniform length of working day is wholly illogical. The human machine should be operated at its maximum beneficiency, — at that rate at which it runs best for the machine and for the product, and for such intervals of time as are best for

the product and for the machine. For hard, monotonous work there should be short days or days with broken periods, just as an army is rested on the march; for varied work the days may well be longer. There is opportunity here for the physiologists and psychologists to study and give advice. We can also hold the laborer in greater respect and provide rewards according to his ability, experience and faithfulness. The coal shortage and the food shortage have emphasized the dependence of human society upon common labor.

It has also seemed to me that the laborer of to-day does not get a fair opportunity to build a home, and next to work, perhaps even more than work, home life determines contentment. The first physical requisite of a home is shelter, family isolation, and a reasonable amount of individual privacy. Homes begin to vanish when cities become congested. Home life in an apartment, whether it be in the north end of Boston or in the Back Bay, tends to shrivel and disappear. A colossal blunder which civilization made in the nineteenth century was to allow cities to overgrow themselves, to allow urban life to develop disproportionately to rural life. Attracted by high wages, by prospects of easy living, by the pleasures which undoubtedly come from the foregathering of the people, the young men and women of the country flocked to the city, only to find in the end that the very elements of life — air, food, water, shelter, clothing — were being obtained with increased difficulty and cost, and that ephemeral pleasures and easy conditions of living were being substituted for the solid satisfactions of home life. The decay of home life is reflected in the steadily decreasing birthrate. (The birthrate to-day for the old New England stock is said to be as low as that of France.) We deplore all this, and wonder what we, as a nation, are coming to; but we fail to attack one of the most vital problems, namely the decentralization of population. Congested city life may be efficient, but in the long run it is not beneficient to the mass of the people. Decentralization does not mean doing away with cities; it means substituting many cities of moderate size for a few cities of very large size. State planning is even more important than city planning.

Because the laborer has not received his fair share of the

satisfactions of life he has endeavored to get them in the form of increased wages. It seems to me that in many cases this has gone too far. When a carpenter or a plumber or a bricklayer gets more money for his work than the engineer who directs the work, — and this has happened repeatedly of late, — when the laborer earns more than the small trader or the bank clerk or the school teacher or the clergyman, it shows that money rewards are not being given in accordance with what people are contributing to society. Granted that the big fortunes and the earnings of capital have in the past been excessive, it is probably true to-day that there is a strong tendency for the laborer to get too much money for the work he does. But when he gets it he still finds that he cannot procure with it the satisfactions of life; his extra leisure and his money are both spent unwisely. In other words, our money standard of rewards has failed. It has over-stimulated enterprise, it has brought about an unwarranted inequality in the distribution of wealth, and it has not brought contentment either to the laborer or the capitalist.

The Engineer and Beneficient Democracy. — The engineer has a unique opportunity to be a great social force in the new democracy, to bring about harmony between work and the worker, to make work beneficient. The engineer is the planner of cities, the designer of factories, the builder of roads and railways, the distributer of power, the digger of mines, the operator of all sorts of industries. What has he planned and built and operated for? Chiefly for product. He ought not to be criticized for that. It is a major element in the problem, and he has been content to consider that as his particular work. But the engineer has greater opportunities than almost any one else to make working conditions and living conditions better for the worker. The engineer is often the inspector of the work done. Why should he not also be the inspector of the worker, and see that his yoke is made as easy and his burden as light as it can be reasonably made? Specifications are drawn for the product of work; why not better specifications for the worker?

It would not be just to say that these things have been altogether neglected. There has been a considerable improvement all along the line in recent years. Health protective

measures are being put into specifications, provision is often made for the housing of workmen during construction; safety devices of all sorts are being rapidly put into factories; welfare work of many kinds is in progress; living conditions are improving; but these things have not been done as a matter of course, but rather by the compulsion of law or the benevolence or the patronage of the owner. The laboring people do not want these things in this way; they want them as a matter of custom and right. In fact, at the present moment the labor unions in America do not appreciate them as a great factor in their problem. They have two principal thoughts, — more pay for less work, and uniformity of pay regardless of ability. The labor unions of this country are far behind those of England in appreciating the importance of the conditions under which men and women work and in planning a constructive program to secure these and other benefits for all the people. The labor unions must have a change of heart if they expect to play the noble part in the beneficient democracy which they can play if they will. There are already signs of this change. The entrance of woman into industry is bringing conditions under which people work into the limelight, for women are by nature more influenced by their surroundings than are men. If labor fails to take the fair attitude, is selfish, and overreaches as capital has overreached in the past, the new democracy will fail. Unless American skilled labor adopts a broad-minded, constructive policy, in which the rights and welfare of all are considered, the pendulum will swing far towards proletariat control and then swing back to autocratic conditions. There should be a serious effort on the part of the engineer to prevent it from swinging too far in either direction.

Engineers perform five principal functions, — they advise, design, inspect, construct and operate. In these functions they come close to capital on one side and close to labor on the other. The advisory or consulting engineer and the designing engineer are almost invariably employed by capital. The constructing engineer, the contractor, and the operating engineer are close to labor, and the laborer's pay often goes through their hands. As an inspector the engineer's attitude is judicial. Sometimes

these functions are bound up in one individual, but more often designing, construction and operation are in different hands. In fact, the contractor and the operator may not be regarded as engineers at all. Labor, as such, is represented in the walking delegate, a sort of malign guardian angel, who knows nothing except the color of the sheep in his flock, and who seldom, if ever, knows anything about the work which is going on. In my opinion, labor should be better represented, and I know of no one better fitted to protect labor than the engineer.

One of the great underlying causes of present-day labor troubles is that the laborer does not understand what capital really is, does not distinguish it from so-called special privileges, from the unjustified control of the resources of nature. To the laborer, capital is impersonal. The laborer does not know the people whose savings make his work possible, or even the person who handles these savings. Conversely, labor is likewise impersonal to the man of capital. In large establishments the employer does not individually know the people who work for him. This personal knowledge, each of the other, appears at first thought impossible of attainment in a complex civilization, with its enormous cities, its far-furrowed fields, its immense factories, its scattered mines. Individually it is impossible, but collectively it is not. The mine president cannot know all the laborers, but he can know some and through them the others. Not all of the laborers on a job can eat lunch with the big boss, but if a few of them did, once in a while, the acquaintance would be mutually beneficial. The greatest of all problems for the engineer is to help build a bridge between capital and labor. As a rule, the laborers like the engineer; they see him on the job, working in old clothes, measuring, planning, directing; they see him eat and smoke, and they regard him as a human being like themselves. They know, too, that the engineer stands in with the man who is furnishing the money to pay for the job. But to properly fulfill this intermediary position the engineer must broaden his ideas of efficiency from that of the most work for the least cost so as to include benefit to the constructing laborer as he constructs, and benefit to the worker who is to use the constructed plant.

I imagine that an architect reading this will say, "I too occupy an intermediary position between capital and labor"; and so will the lawyer and the clergyman and the factory superintendent. This is true. It will take many men to build this bridge and to induce the human race to travel it.

Let us now turn from these social problems in which the engineer is to find his place to matters of a more definite engineering character.

Public Service. — The unmistakable drift towards the adoption of the so-called socialistic program, whether it be permanent or not, seems likely to place engineering work more and more in the public service. The engineers of the next generation will be employed more and more by the nation, the state and the municipality, and their functions will increase greatly in the direction of executive work.

At the present time we have some anomalous situations. Public-service commissions, state boards of health, and similar organizations are called upon to advise, to approve plans and to otherwise pass judgment on the designs and proposed work of engineers acting independently or employed by private capital. The salaries paid to engineers employed in the public service are in general lower than the earnings of engineers in private practice. The positions are often filled by young men, — usually able, but nevertheless inexperienced. Not infrequently it falls to the lot of these men to pass judgment on plans prepared by other engineers who are far more competent and broad-minded than they themselves, and decisions humiliating to the private engineer and unfortunate to the state are liable to result. The obvious remedy for this condition is to so adjust the rewards of public service that the ablest and most experienced engineers will be attracted to it. These rewards must be expressed in reasonable salaries, but also, and what is perhaps more important, in respect and security of office.

During the last few years the so-called "city manager" plan of municipal administration has rapidly come to the front. This is distinctly a recognition of the engineer. A very large percentage of the city managers thus far chosen comprises men chosen from the ranks of our profession.

After the war many of the engineers who have entered the army and navy will doubtless remain in the service.

Many engineers of great ability have, from motives of patriotism, accepted emergency government positions for compensations far below anything they would consider in ordinary times. If in the coming peace times they can be made to feel that they will be doing their country a great service and one for which their fellow-citizens will give them honor, they will gladly continue in the public service. Certainly there are elements besides monetary considerations which control the acceptance of government positions by engineers.

One result of the entrance of the engineer into public executive life, if such reforms as the initiative and referendum prevail, will be a demand that he display a quality not usually conspicuous among engineers, — the ability to describe a complicated project in such a simple and clear statement that the man on the street can understand it. To describe the merits and demerits of a proposed plan before a board of directors with the drawings before them is one thing; to put the same plan before the voters of a city, in the daily press or in public meetings, is quite another matter. Such a city manager as Mr. Waite, in Dayton, owes his success in great measure, I take it, to his ability to make the people get his ideas. The success of democratic government lies in the intelligent interest which the citizens take in what the officials are doing. More and more, therefore, will it be the business of the engineer to educate the public.

Coördination of Public Service. — The presence of men belonging to one profession in different branches of the public service ought to bring about a closer coördination of these branches. Governmental departments are of necessity specialized, and of necessity there must be direct lines of authority; but unless there are cross lines, short cuts from one department to another, there is tremendous loss of efficiency and great waste. We have done well doubtless to emphasize the organization chart, but unless we organize the cross lines we shall not have a perfect organism. In all this we can learn much from the organization of the human body. The nervous system and the

circulatory system are radially planned, but not every function is controlled by the brain. The human body is full of short cuts, and different parts perform many automatic acts. The body politic should also provide for reflex actions.

Such an organization as that of the New York Society of Municipal Engineers, which brings together engineers from all the various departments where engineers are employed, is an example of coördination in a general way. But there is no intrinsic reason why more specific coördination cannot be made as a part of the regular machinery of government.

Conservation. — Professor Swain has said that the conservation of our resources is a social problem. This being granted, is it not the engineer who must guide the people in their use of these resources? He knows the properties, advantages and cost of different resources, and if he will he can advise their use or disuse, looking not only to the benefit of the job at hand but to the possible exhaustion of the supply. He can often find a way to use natural forces instead of power created by the consumption of resources. A gravity water supply instead of a pumping supply may be a wise choice because in the one case coal is used while in the other the force of gravity is used. It is not without significance that the English engineer Tredgold defined engineering as the "employment of the great *forces* of nature for the use and convenience of man." Tredgold did not say the employment of the *resources* of nature. Water power has this advantage over steam power that the rain falls year by year and always will, while coal when it is burned is gone, and more coal can be obtained only with increasing difficulty. Yet, it must not be forgotten that long-distance power transmission by electricity requires the use of copper and other natural resources; and such uses of incidental materials are not to be neglected. In many ways, however, natural forces may take the place of natural consumption of resources. I need not multiply illustrations.

If the state becomes the conserver of the resources of the world, the engineer in government employ will be an important factor in guiding the conservation movement. The war has taught us, as nothing else ever did, the importance of our basic productions.

Foreign Engineering. — The war is getting the people of the world acquainted with each other. It is getting people to think about the resources of the globe in terms of world-wide necessities. It is elevating business, commerce and transportation to a higher plane than they have ever occupied before. It has emphasized the benefits of organization. The Christian missionaries were the first to take the world view. They were ahead of the business man in all of the far-distant and inaccessible places, and by their self-sacrificing labors they paved the way for a universal civilization. But the business man followed after the missionaries, and the threads of commerce are gradually binding the countries together. Hence the engineer is more and more to find a field for his service abroad.

When one considers Russia and Siberia, — with their resources of field, forest and mine, — China, Japan, the Philippines and India, and when one considers also Africa, South America, Mexico, Cuba and the many tropical islands, it is evident that the resources of the world are very far from being exhausted. More and more must the engineer think in terms of the world.

But in doing so the idea of exploitation must forever be renounced. Of course there must be profits commensurate with the effort; there must be business stimulus; but in the new democracy these rewards must be widely distributed, and the conservation of resources of other countries must be practiced as well as the conservation of our own. To over-develop foreign commerce in natural productions would inevitably lead to further wars. Beneficiency must be practiced abroad as well as at home. The work of engineers in foreign lands will greatly help solve our own problems. Let us take, for example, the control of Chinese floods, the greatest hydraulic problem in the world. If American engineers can help China solve this problem, the problem of the Mississippi will afterwards be as child's play. If American sanitary engineers can teach China how to solve her sewage disposal problem and to utilize the fertilizing elements of human beings in a decent manner it may revolutionize sewage disposal in America.

Foreign service is especially attractive to young men.

The scattering of young men through the English colonies has been of great benefit to Great Britain. It would be well for us to encourage such service in order to interest our educated and influential young men in governmental work and thus raise the standard of the personnel engaged in such work.

Domestic Engineering. — It is not necessary to go abroad to find new fields and new problems. The present war has done much to expand the field. One of the most interesting is the entrance of the engineer into the field of domestic engineering, or, in other words, housing. The health reports of fifty and seventy-five years ago were full of the needs of better housing, and, although a great deal has been accomplished in that time, we are still talking about new building laws and housing laws, and complaining of non-enforcement of regulations. The laws are indeed chaotic and archaic, flawful and awful.

Until recently the engineer has not taken a leading part in providing shelter for the people. House building has been largely an individual matter. But the war has changed all this. Now we see the uncommon sight of engineers constructing houses by hundreds and thousands, building military towns and camps, and organizing companies for wholesale house building. The demand for low-priced houses has become pressing, and the need of temporary houses of laborers at many war plants has been enormous. Engineers and architects are working out details of design and standardizing methods of construction. In standardizing building construction we can learn much from the Chinese. In China and in Korea a beam is a beam, and a board is a board. Houses are built of beams and boards of standard size. Even ornamental features, such as brackets, etc., are standardized. Beams taken from an old house may be again used in a new house. Scaffolding is used over and over. All this has been from necessity, nevertheless it makes mightily for conservation, and does not produce a dreary monotony of buildings, as one might think. With the eyes of the engineers once opened to the possibilities which exist, we may expect to see the whole problem of housing approached from a new point of view and given a strong push towards solution.

City planning is another phase of this problem, and is, of

course, much broader than housing. The restriction of buildings in height, bulk and use as in the recent law of New York City is an important development.

Engineering Education. — While I have been using the word "engineer" in the singular number, it is obvious that to carry out the functions outlined the engineering profession must be a great composite of specialists and must contain also many men of broad attainments, education and experience. But all of the varying types of engineers must be held together by a common bond, and that bond is *science.* The engineer applies science, drawing upon natural resources and the forces of nature in a large way for the use and convenience and happiness of man. The love of physical science, respect for mathematical law, and a constructive imagination are the foundation qualities of an engineer, but along with them must go an appreciation of human needs and desires.

To provide this body of specialists in applied science it will be necessary to maintain many engineering schools and to have these differ from each other. There must be manual-training schools, technical schools, and university schools of applied science; schools with courses of two years, four years, five and more years; schools with the usual academic terms, schools which run the year through, schools in which work and instruction are alternated, and schools in the evening. To have all technical schools standardized would be most unfortunate. To have a large number of moderate-sized schools might be better than a few very large schools. Overgrown schools have some of the faults of overgrown cities. There should be more competition in engineering education, but at the same time more coöperation in the use of large and expensive laboratories and machinery and more cross connections between schools.

The war has completely and forever broken down the barrier between pure science and applied science. The teacher of pure science is no longer to live in isolation, to be placed on a pedestal or scornfully regarded as a theorist, and the man whose instincts are for organization and for the utilization of what is known, must not claim too much for his achievements. So also has

the barrier broken down between the arts man and the science man, and in my opinion the return to the study of the classics, of language, of literature, of history and of government by men who are planning to be engineers will take place to an increasing extent. The wider work in engineering will need a broader foundation.

Professor Mann, in his studies of engineering teaching in America, has emphasized the needs of character building and personality as primal requisites, and the importance of studying science, engineering practice and the cost of works, and holds that the last two are receiving too little attention in the schools to-day. The reason why this has not been done is, of course, obvious; namely, that in the ordinary four years' course there is not time to study all of the necessary fundamental subjects and at the same time go very far into such matters as practice and cost. To do this properly requires more than four years of study. There ought certainly to be ample opportunities given young men for such extended studies in our great universities. Students intending to be lawyers, ministers or doctors expect to study not four years only, but six or seven. Why should the young man who wishes to become great in the profession of engineering expect to give less time to his preparation for a life's work? In the new democracy the country will need more men of this type.

The Engineering Society as a Graduate School. — On the other hand, many young men cannot afford to study more than four years, some cannot give even that time; and the engineering graduate does not immediately begin to practice or preach, as the doctor or the minister does, but, whatever his training, begins at the bottom and works up. This apprenticeship is necessary, and no amount of schooling can replace it. If the time in school is limited, it is all the more necessary, in my opinion, that it be spent in learning fundamental principles, and that specialization be not carried too far, — not as far as it often is to-day. Where, then, is the young man, the ordinary technical school graduate, to learn about practice and costs and all that? It seems to me that here is an opportunity for the engineering society which has thus far been neglected. Conditions ought to

be such that the graduate in engineering entered some professional engineering society as a matter of course. Here he ought to find opportunities for learning about engineering practice and costs, in the best of all ways, — that is, by coming in contact with engineering works themselves and the men who build them. It would not be a difficult matter for engineering societies to offer short courses of lectures given by the older members for the benefit of the younger. And I venture to say that members no longer juniors would be glad to attend such short courses in order to refresh themselves. Too much have our society meetings become mere formal lectures illustrated with lantern slides. These are all very well, but they are not enough. We need the more frequent meeting of small groups. I offer this as a recommendation, — that the Boston Society of Civil Engineers arrange for a few series of short lectures in engineering practice during the coming year, for the benefit of members of the Society.

Individualistic Democracy. — My final thought recurs to the new democracy. I believe that when the good features of the socialist program have been sifted from the bad, — the good ideas adopted and the bad discarded, — there will follow a new organization of society in which individuality will be the prominent note. Although a democracy, it will be a highly specialized and well disciplined and organized democracy, where the natural inequalities of men and women will be recognized and rewarded, but where all will have an equal chance to obtain the great satisfactions of life. But we shall never arrive at this condition unless our students throughout their entire school age are taught to develop their own personalities, unless we adopt some form of democratic military discipline, unless efforts are made to find the right job for the right man, and unless more efforts are made to bring different classes of workers and employers to sympathize with each others' contribution to the common good. But, above all and before everything else, we must win the war.

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BOSTON SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

ECONOMY IN THE USE OF FUEL IN POWER STATIONS.

By Charles H. Parker,* Member of Boston Society of Civil Engineers.

(Presented before the Sanitary Section, March 6, 1918.)

The Fuel Administrator has lately said that New England needs about 32 000 000 tons of bituminous coal next year. By far the larger part of this is used for power purposes. The cost of this bituminous coal is very large, say $320 000 000, so any general saving of even a few per cent. will run into large figures. Beyond this is the question of transportation facilities and the question of adequate supply of our needs at any price. A saving of only one per cent. due to more economical burning of this coal would mean the release of one 10 000-ton collier for a year, or that the railroads could release 6 400 50-ton coal cars one trip a year for other work. There are many plants where a substantial saving can be made, and very few plants indeed where no saving at all can be made.

The bituminous coals used in New England for power purposes come almost exclusively from Pennsylvania, Maryland or West Virginia, and are among the best coals mined in the United States. The following figures (Table 1), taken from a report of the Boston Chamber of Commerce a few years ago, show the average analysis to be expected in peace times. During the

* Supt. Generating Dept., Edison Electric Illuminating Co., Boston, Mass.

rush of war times, with less careful mining and selection, the ash contents may run considerably higher, and consequently the B.t.u. run lower than given.

TABLE 1.

District.	Moisture.	Volatile.	Fixed Carbon.	Ash.	B.t.u. Dry Basis.
Broad Top, Pa.	0.71	15.84	72.05	10.50	14 015
Clearfield, Pa.	2.39	20.47	67.41	9.73	14 086
Cambria, Pa.	2.53	19.50	69.50	8.47	14 324
Somerset Co., Pa.	2.55	17.53	70.52	9.40	14 238
Jefferson Co., Pa.	1.54	30.35	58.55	9.56	13 875
Indiana Co., Pa.	1.32	22.78	65.30	10.60	14 048
Westmoreland,* Pa.	3.25	31.08	55.20	10.45	13 849
Pittsburgh, Pa.	2.75	33.91	56.28	7.06	14 259
Georges Creek, Big Vein, Md.	3.02	18.58	69.93	8.47	14 350
Upper Potomac & G. C. Small Vein, Md. & W. Va.	2.75	20.16	67.02	10.07	14 051
Fairmont, W. Va.	2.48	36.35	53.60	7.57	14 166
New River, W. Va.	2.98	20.47	70.21	6.34	14 696
Kanawha, W. Va.	3.49	32.39	57.40	6.72	14 309
Pocahontas, W. Va.	2.86	17.59	72.40	7.15	14 661

With volatile contents running from under 16 per cent. up to over 36 per cent., fixed carbon from 54 per cent. to 73 per cent., and ash from 6.34 per cent. to 10.60 per cent., it becomes very evident that these coals will not all burn alike and that conditions suitable for one coal may not be suitable for another.

Combustion of coal takes place in steps: (1) It absorbs heat to dry it and raise it to the ignition temperature. (2) The hydrocarbons or volatile portion of the coal has to be vaporized and supplied with the necessary oxygen for combustion. (3) The solid or fixed carbon of the coal has to be supplied with the necessary oxygen for combustion.

While the second and third steps are taking place simultaneously, the combustion of the volatile portion is completed long before combustion of the fixed carbon. Where coal is fed in quantity, as in all hand firing, efficient combustion demands that a large volume of air be supplied immediately after coaling, and after the volatile has been burned a lesser amount of air for the combustion of the fixed carbon.

* Eastern part.

Another point to be remembered is that during combustion the particles of burning gas or carbon must not be allowed to cool below the ignition temperature, or combustion will cease, with consequent formation of soot and smoke and the loss of heat.

Approximately $7\frac{1}{2}$ lbs. (100 cu. ft. at 70 degrees fahr.) of air per 10 000 B.t.u. are theoretically required for perfect combustion. Due to the impossibility of properly mixing the combustible with the air so as to bring each atom of air to an atom of combustible, excess air must be given for complete combustion.

The aim in all boiler work should be to get complete combustion with the smallest excess of air possible. The best way to find what excess air has been used is to measure the percentage of CO_2 in the flue gas. Best boiler practice rarely exceeds 15 per cent. CO_2, and 12 per cent. to 14 per cent. is good. Anything less than 12 per cent., however, shows loss of heat in chimney gases due to too great an excess of air. Many places have been found where the CO_2 averaged only 5 per cent., showing an excess of air of some 214 per cent.

With a flue gas temperature of 550 per cent., the heat carried away by the dry chimney gases per pound of carbon burned as given by Babcock & Wilcox Co. in "Steam" (p. 158) follows:

15 per cent. CO_2 = 27 per cent. excess air = 1 800 B.t.u.
12 per cent. CO_2 = 54 per cent. excess air = 2 200 B.t.u.
5 per cent. CO_2 = 214 per cent. excess air = 5 250 B.t.u.

Carbon has value of 14 540 B.t.u. when burned to CO_2, so the above losses in heat become —

For 15 per cent. CO_2 . . . . 12.3 per cent.
12 per cent. CO_2 . . . . 15.0 per cent.
5 per cent. CO_2 . . . . 36.0 per cent.

The loss due to incomplete combustion or the formation of CO instead of CO_2 is not serious in most plants unless the combustion chamber is much too small. This is rather difficult to change in an existing plant, but if analysis of the flue gases shows any considerable amount, say .25 per cent., steps should be taken to remedy it. In all new work allow plenty of

combustion chamber space, so the gases can be all consumed before they impinge on the heating surfaces. In striving for the higher percentages of CO_2 in flue gases, care must be exercised to see that CO is not formed, for a pound of carbon burned to CO only gives 4 380 B.t.u., while if burned to CO_2 it gives 14 540 B.t.u. Proper admission of air and liberal combustion chambers keep this loss a minimum.

The loss due to combustible in the ash depends on the type of grate or stoker and the carefulness of the fireman in firing and cleaning the fires. This loss may amount to ten per cent. of the fuel. The openings in the grate or stoker should be proportional to the kind of coal to be used, a non-coking coal requiring smaller openings than a coking coal. It is often possible to save a lot of these siftings, especially with stokers, by installing proper hoppers or pans to catch them and keep them out of the ashes. A periodical examination of the ashes carted away is well worth while.

The loss due to water in the coal is twofold — first, if bought with the coal it is very expensive as each per cent. of water means a per cent. of coal paid for and not received; second, it has to be evaporated and superheated to flue temperature. Both together mean about 1.1 per cent. loss for each one per cent. water in the coal.

It is sometimes helpful to wet the coal just before firing on ordinary hand-fired grates, to prevent the rapid release of the volatile hydrocarbons and give a chance for them to be consumed also; on some overfeed stokers wetting may prevent excessive sifting. In each of these cases the loss due to evaporation and superheating to flue temperature is present, but the other gains more than offset it. The water only acts in a mechanical way and adds no heat.

The loss due to visible smoke is usually very small, rarely reaching one per cent. of the coal fired, but dense smoke quite often means bad conditions elsewhere. If the coal is fed in too large amounts, considerable hydrocarbon may be discharged without being burned. It may also indicate too small a combustion chamber. A smoky chimney, however, may be more economical than a clear chimney if the latter is obtained by exces-

sive air dilution. Our smoke-prevention laws make a smoky chimney a nuisance and too expensive to maintain.

Standby losses may be considerable in plants having a fluctuating load, and consist of coal required to start up cold boilers, coal used to bank fires during shut-down periods, heat lost in shutting down boilers, and heat lost in water blown off to get rid of mud and scale from mud drum. The magnitude of these losses are dependent on the character of the load to be carried. Where boilers are not needed for more than twenty-four hours it is usually cheaper to let them go out and build new fires rather than bank them. See that the damper between the boiler and the flue is in good condition, and open only enough during banked periods to carry away the gases, as a badly fitted damper or one left open too wide allows surprisingly large quantities of air to flow through the boiler and cool it.

Flat grates with hand firing work satisfactorily up to 150 horse-power on return tubular boilers and 300 h.p. on water tube boilers, but above that size smokeless combustion is difficult without special arrangements such as Dutch ovens, the Chicago settings, or steam jets.

The Dutch oven containing the grate is placed in front of the ordinary setting. This gives a mass of hot brickwork to heat the liberated volatile matter to ignition temperature, and increases the combustion chamber space, thus giving the gases time to finish combustion before striking the relatively cold boiler surfaces. This may be used on either return tubular or water tube boilers.

The Chicago settings consist of combinations of firebrick arches, baffles and piers built in the combustion chamber to mix the air and volatile matter of the coal and help maintain them at ignition temperature. This is used on return tubular boilers.

Steam jets pointed downward, for forcing extra air over the fire at the front wall, through the side walls, or even through the bridge wall, and mixing it with the volatile matter from the coal, often show good results, both in better efficiency and a lessened amount of smoke. Unfortunately, when these depend on the fireman for operation they do not show the same results commercially as on test. They should be used only while the

volatile matter is being driven off, and should be shut off afterwards until the next charge of coal is fired. The ordinary fireman either won't use them at all or will leave them on all the time unless he is closely watched. In the first case, cost of installation has been wasted, and in the second case a lot of steam and the efficiency not bettered, — in fact, it may have been reduced. Steam air injectors can be made automatic and therefore independent of the fireman, but they need careful adjustment to obtain the best economy.

Down-draft furnaces are made with two grates, one above the other. The upper one is made of parallel water tubes connected through headers or drums to the water space of the boiler in a proper manner to insure positive circulation of water. The bottom grate is an ordinary flat grate. Coal is fired on the top grate only. The upper front doors are always left open, and the air passes down through the green coal, mixing with the volatile matter distilled off, and then passes over the incandescent fire below. The lower grate is fed by the half-consumed coal sliced down from the upper grate. Lump coal gives better results than slack, as the latter is apt to fall through too freely. This equipment gives very good efficiency and smokeless combustion where it is carefully handled, not forced, and has the boiler tubes properly covered with fire tile.

Shaking grates assist the fireman in cleaning the fires, often decrease slicing, and assist in maintaining the fire in a loose or broken up condition so the air can get through better. This helps economy, but their general use has been to assist the fireman in getting more capacity.

Semi-bituminous coals, such as New River, Pocahontas, Clearfield, etc., work well with a fire twelve to fourteen inches thick, and should be fired every ten or fifteen minutes. The more volatile coals used in New England are harder to burn efficiently, and the fires should be thinner. With our most volatile coals the fire should not be more than seven or eight inches thick. The thinner the fire, the more often should coal be put on.

The two methods of hand-firing coal used are the coking and spreading. In the coking method considerable coal is fired

at the front of the grate and allowed to coke. After the gases have been partly driven off it is pushed back on to the rear part of the fire. This keeps a bed of incandescent fire at the back, over which the volatile matter and air have to pass, and the high temperature assists them in combining. This method is good where the gases have to travel back, as in a return tubular boiler. In the spreading method but little fuel should be fired at one time, and it should be placed evenly over the fire all the way back. Where there are two doors to a furnace, fire them alternately, as the bright fire on the other half of the grate materially assists in burning the volatile matter. This method is good where the path of gases is straight up from the fire. Hand firing produces its best results when it imitates the mechanical stoker, that is, when the coal is fed in very small quantities at short intervals, but has this disadvantage that large volumes of cold air are admitted with each charge of coal.

In large plants, having mechanical means for delivering the coal to the stokers and easy ash removal facilities, mechanical stokers will save considerable labor. In small plants, however, where the coal would have to be shoveled into the stokers and the ashes taken out in wheelbarrows, or barrels, no labor will be saved, and the only justification for installing mechanical stokers is fuel saving and smoke prevention.

Interest on the investment, depreciation, repairs and power for operation are all larger with mechanical stokers than with hand-firing; but mechanical stokers make possible the use of poorer fuels with as high or higher efficiency than is obtainable in hand-firing with better grades of fuel.

Mechanical stokers divide themselves into three general classes: (1) Chain grates, (2) overfeed, (3) underfeed.

Chain grate stokers, such as the "Babcock & Wilcox," Green, Illinois, etc., consist of an endless chain, or belt, around sprockets at the front and rear of the furnace. The belt is made up of short links, sections or bars. The coal is fed by gravity from a hopper on to the front end of the grate, and is carried back to the bridge wall by the grate. During the first part of this travel it is under an ignition arch which drives off the volatile matter and ignites it and the solid carbon. Dampers or

baffles should be arranged under the different parts of the grate to control the admission of air. A water box or dampers should be used at the rear end, to prevent excessive leakage of air. The coal is supposed to be all consumed and nothing left but ash when it arrives at the rear end — refuse falls over the rear end, so no cleaning is required, ordinarily.

The chain grate will handle coals high in volatile and ash with very good economy, will be smokeless, and the cost of upkeep will be small. It is not fitted, however, for coals low in volatile matter and ash, and where used with these coals the repairs are excessive and the efficiency poor.

Overfeed stokers divide themselves naturally into the front feed and the side feed. Front feeds are represented by the Roney, Wilkinson and Acme. They have a hopper at the front end, the grate slopes downwards and backwards at about forty-five degrees, the bars or ledges tip and drop the coal from one bar to the next, until it finally reaches a small, flat dumping section at the rear, where combustion is finished. When considerable ashes have collected, the fireman cleans by dumping the grate. Small coking arches at the front ignite the fuel as it starts its travel, and the bright fire below materially assists complete combustion.

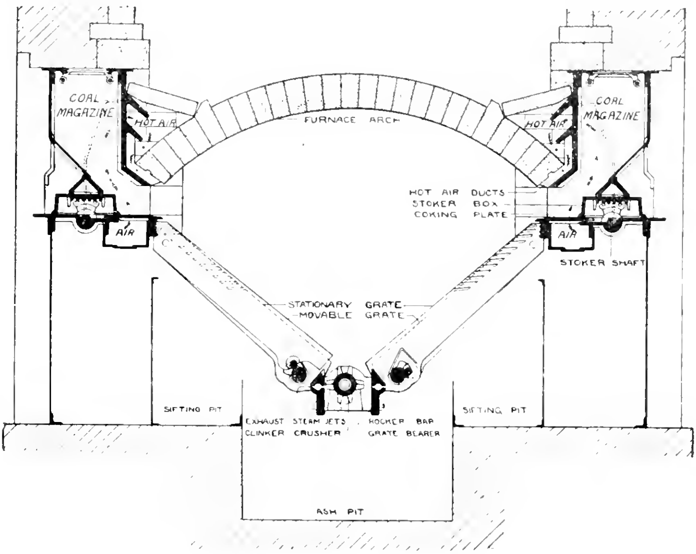
The side feed stokers are represented by the Murphy, Detroit and Model, and illustrated by the Murphy (Fig. 1). Here there is a hopper at each side, the full depth of the stoker, pusher plates feed coal on to bars which slope down to the center. Alternate bars are rocked at the bottom end and pivoted near the top. This rocking carries the coal to the bottom of the V, where a clinker grinder drops the ash and clinker through to the ash pit. These stokers have a full fire-brick arch over the whole of the stoker. Hot air is delivered from under the coking plates and the haunches of the main arch to the freshly ignited coal.

All the overfeed stokers are useful for burning semi-bituminous coal when not unduly forced, that is, will handle loads from 100 per cent. to 150 per cent., of rating nicely, and can be forced to around 200 per cent., but the higher rates cause rapid deterioration. The side feed, due to the full ignition arch, are nearer

smokeless than the front feed although all of them are satisfactory from this point when carefully handled at light loads.

The underfeed stokers are represented by the Jones, American, Taylor, Riley and Westinghouse, illustrated by the Taylor (Fig. 2) and Riley (Fig. 3).

They all use forced draft. The Jones and American are horizontal, and the others are inclined. The American uses a screw, and the others all use rams to feed the coal in under the



TRANSVERSE SECTION.
FIG. 1. MURPHY SIDE FEED STOKER.

fire. With the Jones and American, the coal wells up over the sides and end of trough and the air is forced through tuyère blocks around the trough. Ashes have to be hand cleaned from the dead plates around the troughs. These are usually used on small-sized boilers only.

The Taylor, Riley and Westinghouse are inclined; the main rams feed fuel at the top of the troughs. Taylor uses auxiliary rams, Riley uses reciprocating tuyère sections, and Westinghouse main ram feeds at inclination of grate, to assist the movement

of fuel to the bottom, where various kinds of dumping grates, pusher plates and grinders are being tried for getting rid of the ashes. All of them are built up of troughs with sections of tuyères between. There is always one more section of tuyère blocks than there are troughs. These stokers, due to the forced draft, can operate with heavy, thick fires, burn coking coal well, are smokeless, and can be forced to very high overloads. Good quality firebrick must be used in the settings of the boiler and grate, as they produce very high temperatures. They are expensive to install, and the fans have to be maintained, but the

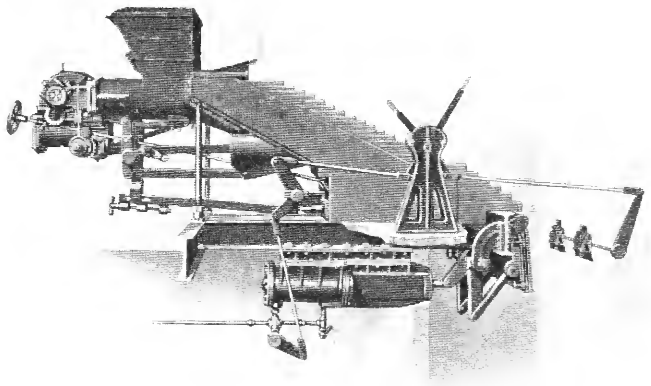


FIG. 2. TAYLOR UNDER FEED STOKER.

chimneys do not have to be very tall and cost of maintenance is not excessive. They make very little smoke when carefully operated. All underfeed stokers can burn the cheaper grades of coal economically, and one man can fire 3 000 or 4 000 h.p. of the inclined type — but not so many of the horizontal type, due to hand cleaning.

At the present time, unless an addition to plant is required by reason of increased load, the question of fuel saving resolves itself into the best use of the existing plant rather than replacing with new, as the costs are very high and deliveries cannot be made for a year or more in many cases.

Spend a few minutes every day if possible in the fireroom,

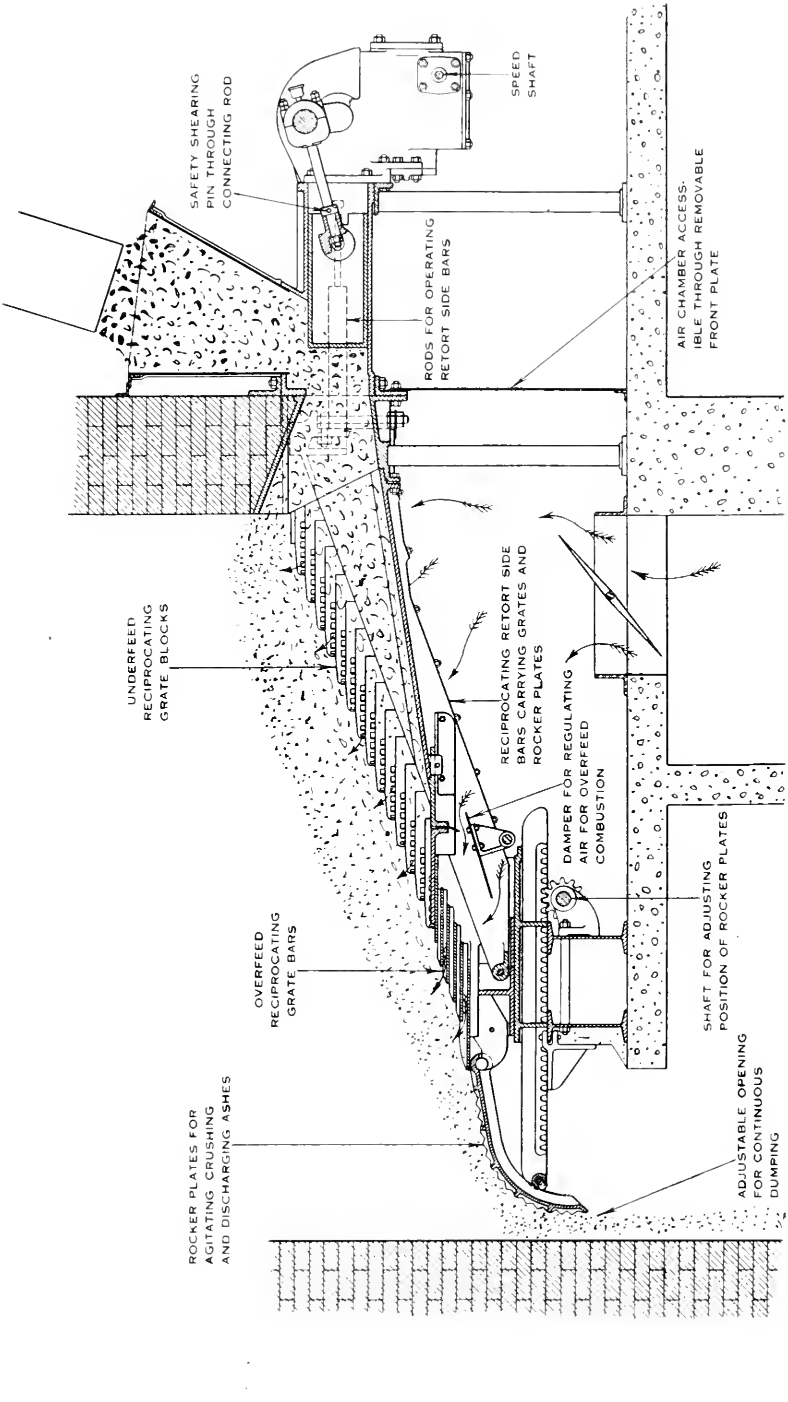


FIG. 3. RILEY UNDERFEED STOKER.

watching the men at work, and see how they are performing it, also talk to them about it. There are lots of firemen who are good men but who from lack of training and superintendence have fallen into very careless ways. The easiest way is quite often not the most efficient. It is often easier to keep a good steam line with a very heavy fire 16 or 18 ins. thick when an 8 or 10-in. fire would be much more efficient, but the thin fire requires much more frequent attention. The more volatile matter the coal contains the thinner the fire should be. With a thick or a thin fire, it is easier for the man to put in 25 shovels of coal at 25-minute intervals than to put in 14 shovels of coal at 15-minute intervals, because when hoeing and slicing are taken into account the latter method will keep him moving most of the time and the former method allows some rest between, even if he has to shovel more coal actually.

Fire often and light. Don't break up the fire any more than is necessary. Fire one half at a time only. Keep a level fire and allow no holes to burn through. All firemen know this but few really carry it out without watching.

Mechanical stoking also needs careful attention. Do not allow holes or craters to form, do not slice or break up fire with hand tools any more than is necessary. New firemen are very prone to do this, and beyond a limited extent it does more harm than good. Keep the apparatus in good working order so that it will function properly.

In both hand firing and mechanical stoking see that the air supply is adequate and properly regulated to the needs of the fuel and load. By adequate I mean sufficient in amount. I have found a number of firerooms that were so tightly shut up, in winter time especially, that there was a considerable vacuum in them. I once measured a vacuum of several tenths of an inch of water column.

The Babcock & Wilcox Company, in "Steam," give a diagram showing that .5 in. effective draft on the grate will burn thirty-two lbs. coal per sq. ft. of grate and .4 in. effective draft will only burn $27\frac{1}{2}$ lbs. coal per sq. ft. of grate, a loss of 14 per cent. in capacity. Adequate quantities of air should be supplied even if it is necessary to heat it by steam coils, to make the

room livable for the fireman. The condensed hot water can go right back into the boiler.

Hand dampers on the boilers should be set to give the requisite draft for the work to be done by the boilers and not opened wide, as is usually the case. If properly set, especially

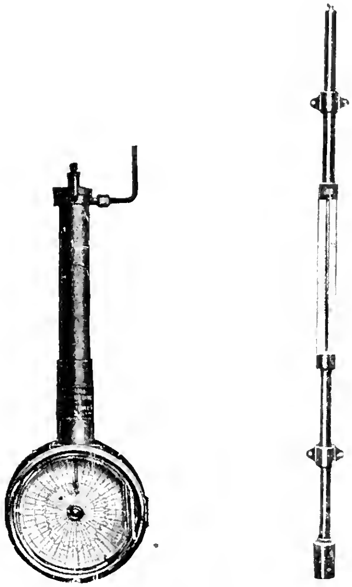


FIG. 4. UEHLING CO_2 RECORDER AND UEHLING BOILER FRONT INDICATOR.

with mechanical stokers, the operation of the main damper will be lessened and the efficiency of the plant increased.

Due to the ease of analyzing the flue gases and finding the percentage of CO_2, and therefrom the economy of combustion, many devices have been brought out to do this with considerbale success either as indicators or as combined indicators and recorders. The simplest is perhaps the Orsat apparatus, but this needs attention and only tells the story for the time at which the sample is taken. A sample can be taken in a bottle, covering a considerable period of time, however, and then a single determination will give the average efficiency during the period.

A better method is to use one of the recorders such as the Uehling (Fig. 4), Sarco, etc., as this gives a continuous record and the fireman can see the effects of his operation. Any CO_2 instrument to record true results needs some little attention itself, and the boiler setting should be tight. The samples are taken in the uptake, and any infiltration of air lowers the apparent CO_2. A good fireman can't make a good CO_2 record if the setting leaks. All CO_2 recorders lag considerably, and need attention.

When several boilers are needed in a plant, a steam flow meter on each is very useful to the man in charge, as he can then easily see which men or boilers are not doing their fair share of the work. There is no economy in having some boilers at very high capacity while others are loafing. The same applies to the men. These help the men also, for if a hole develops in the fire the steam output will drop rapidly, showing that attention is necessary. The General Electric Company and The Bailey Meter Company have good instruments of this class.

Draft gages, showing the draft in various parts of the boiler, are very helpful to a good fireman, or his superintendent, in maintaining proper air proportions. These may be procured of various patterns, from the simple U-tube to types like the Precision Instrument Company's indicators.

The Bailey Meter Company has a boiler meter (Fig. 5) which records on a chart the steam flow on one pen, the gas flow through boiler on another pen (slightly behind the steam pen), the flue temperature, and the draft. The steam flow is obtained by an orifice in steam pipe. Gas flow is obtained by using drop through the boiler instead of an orifice. By the construction of the meter the gas flow pen should track the steam flow pen when the predetermined per cent. CO_2 is taking place. If the gas line gets much above the steam line, too much air is being used or there is a hole in the fire, or the setting leaks somewhere. Conversely, if gas line is much below steam line, too little air is being used, and unconsumed carbon is probably going off as CO instead of CO_2; also smoke is probably being made, laying you liable to a fine, and also depositing dust in the boilers, decreasing efficiency until next cleaning period. This meter,

while expensive as meters go, is rugged, accurate and requires very little attention.

Weighing the coal and measuring the water fed to boilers by water meter, weighing device, V notch meter, or Venturi meter, or any other reliable device, is well worth while if studied. Like all other data, however, unless studied and the results acted on to better the efficiency, they are a waste of money.

With a given coal the air, coal and steam quantities should

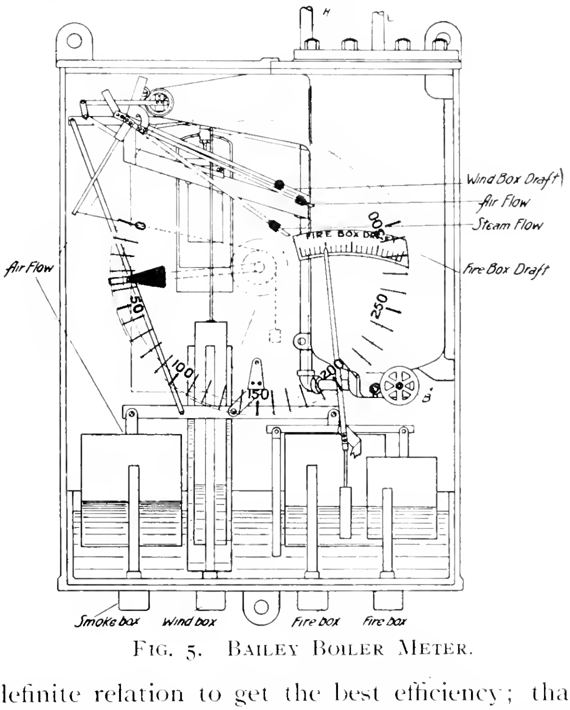


FIG. 5. BAILEY BOILER METER.

bear a definite relation to get the best efficiency; that is, with different coals the ratios are different, but with a given quality of coal the ratios are fixed, so instruments have been devised to give these. One consists of an electric tachometer operated from the stoker shaft, with auxiliary scales to show coal fed and the force of draft required for best efficiency. When properly graduated for the coal being used, these help the fireman maintain good operating conditions. Draft gages are needed in addition to this instrument, however. These instruments are rugged and require very little attention.

Instruments like U-tubes, for measuring draft, are hard to keep clean and are very hard to read in a boiler room, especially after looking at a fire. The newer type instruments all have dust-proof cases, and are much easier to read.

A control panel centrally located, with all of the meters and controls for the operation of one or several boilers mounted on it, is worth every cent it costs, as the stoker operator can tell at a glance which fire needs attention and which are operating satisfactorily. Without this a man must move continually from one fire to another, open doors to inspect the condition, and then not half know due to the blinding glare of the fire; also less opening of doors decreases the amount of cold air admitted, so the economy is better.

There are many places around a plant where a little attention will return considerable savings in fuel. I refer to the leaks. Leaks are of many kinds. There is the leakage of coal as siftings into the ashes, due to too small a shelf or hopper under the stoker; also loss of unconsumed carbon in ash, due to careless cleaning of fires, or by clinker grinders running too fast. There is the loss of heat due to leakage of air through furnace and boiler walls. Keep your settings tight; there are several plastic cements that are good for filling cracks in the brickwork. See that the baffles or flame bridges in the boilers are tight; if they are not, the hot gas short circuits to the flue and escapes without giving up all the heat that it should. Take a look at these yourself, and while looking at them also see if the heating surface of the boiler is clean. Soot is a good non-conductor of heat, and you can't expect good absorption from insulated surfaces. Cleaning heating surfaces is a rather dirty job and disagreeable, but must be done faithfully or the plant efficiency suffers. Permanent soot blowers such as the Vulcan, Diamond (Fig. 6) or Bayer's, make it much easier to keep a boiler clean and use less steam than the ordinary hand lance. They should be picked with judgment, for the particular type of boiler to be used; if the boiler is high and thin, a side-cleaning device like the Bayer is good; if very wide, the side-cleaning type won't clean way across, and the top- and bottom-cleaning type, like the Vulcan and Diamond, is better. If any of the

elements must be very close to the fire, the calorized metal of the Diamond will probably give the better life These mechanical cleaners use only about two thirds of the steam the hand lance requires, and do better work generally.

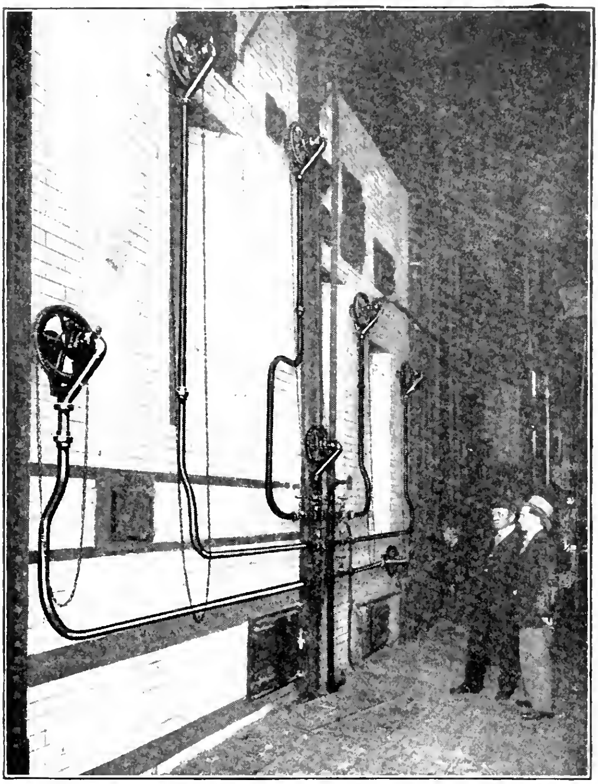


FIG. 6. DIAMOND SOOT BLOWER.

Be sure that the blow-down valve doesn't leak; a small leak here working 1 440 minutes a day will carry away a lot of heat. A good preventive is to use two valves, or a valve and a cock, using one for blowing and the other for holding. Always blow with the same one, so the other will stay tight. Feel of the pipes often — a hot pipe shows leakage.

If steam can be seen anywhere inside or outside of a plant, coal is being wasted. All piping should be kept tight. If steam is being exhausted outdoors make an investigation and see if all is being saved by feed-water heating that is possible. See

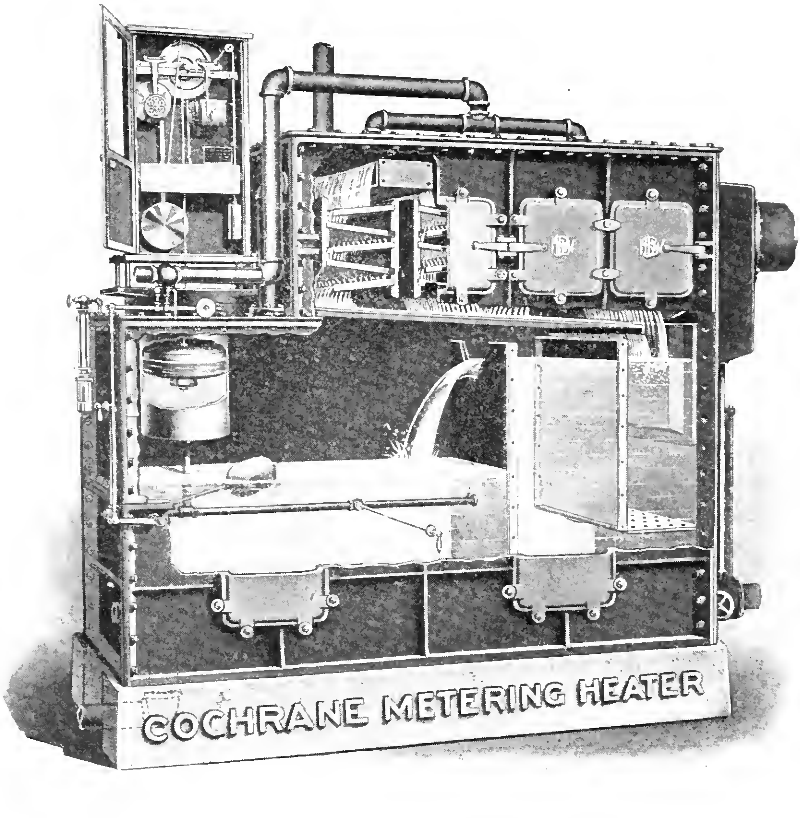


FIG. 7. COCHRANE METERING HEATER.

if exhaust steam cannot take the place of some live steam that is now being used. Exhaust steam contains a very large percentage of the heat originally given it by the boilers, and can be used for many heating and drying processes. There is a prejudice against it in many places that should be overcome.

Steam traps, unless kept in repair, allow considerable loss

of heat. Drip pipe ends and trap discharges have a great habit of concealing their ends under water or in out-of-the-way places.

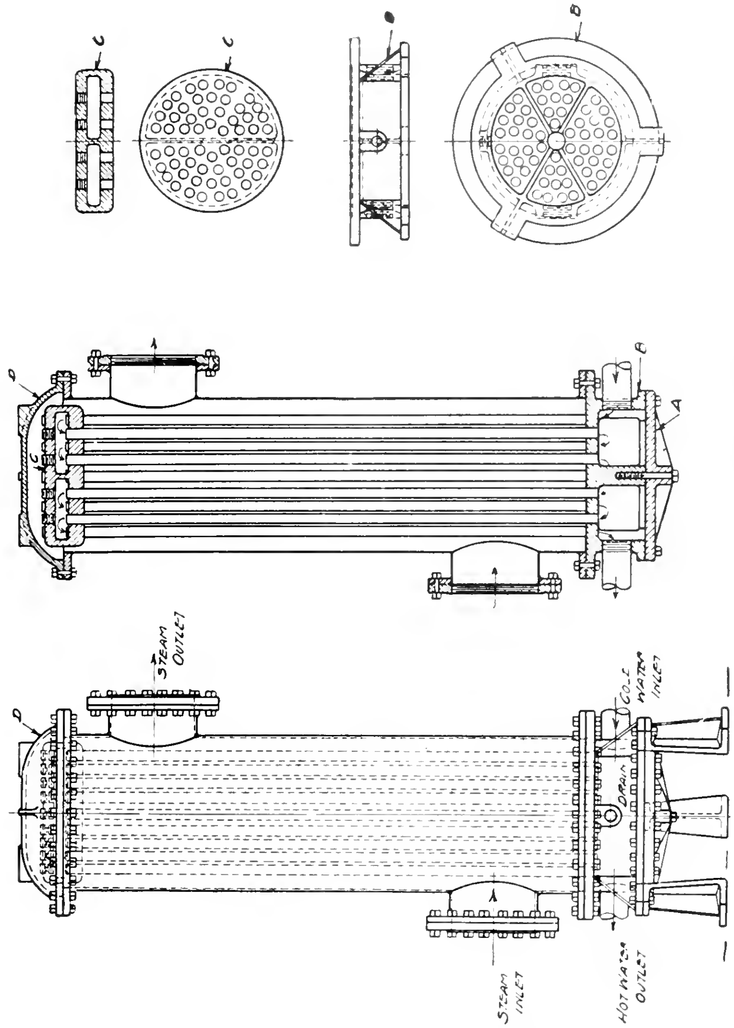


FIG. 8. SIMS TUBULAR HEATER.

This helps the appearance of the plant if they leak, but tends to carelessness in their upkeep. If you can't return these wastes to the feed-water heaters or the system somewhere, at least keep the ends in sight so you know they are tight.

A log sheet giving the starting and stopping of machines and boilers, pressures, temperatures, vacuums, and loads car-

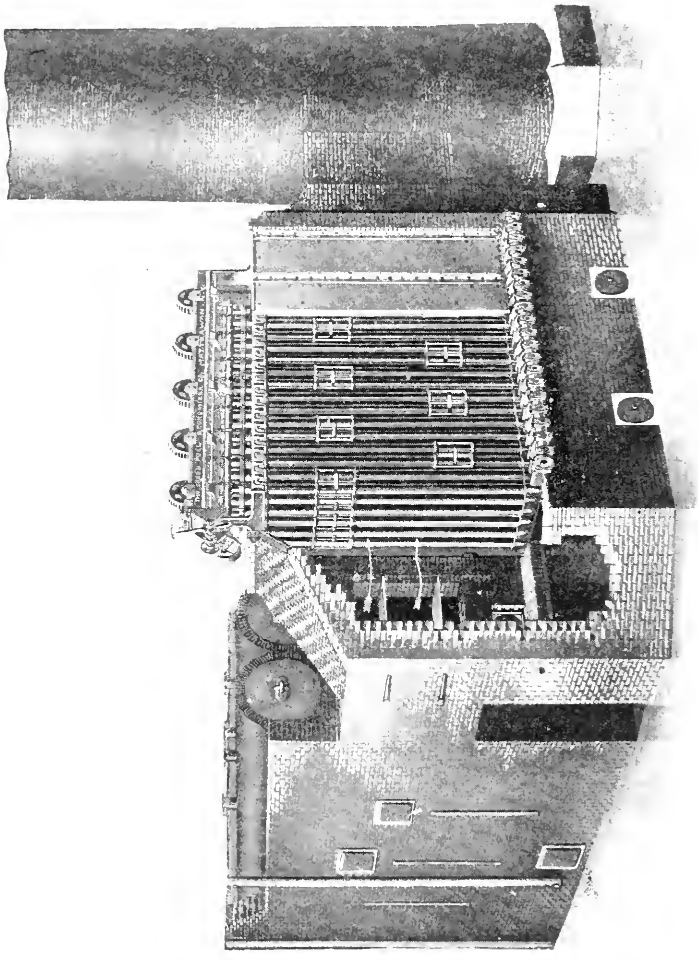


Fig. 9. Green Fuel Economizer.

ried, is wasted effort and material unless it is studied and the facts discovered used for bettering the efficiency.

If steam pressure drops, every one usually knows it, but if

feed-water temperature is low all of the time, who is doing anything about it? Is there any heat being wasted that can be saved by heating it? Is the flue gas temperature high, normal or low, and why? If normal, is it due to good operating conditions, or to a large excess of air counteracting dirty heating surfaces? Is the evaporation per pound of coal good? If so, is it due to good operation or only apparent, due to blow-down valve leakages, blowing down, and general wastage of water around the plant, wetting down ashes, etc.?

Is the vacuum proper for the type of prime mover used? Generally speaking, 25 or 26 ins. on good steam engines and the highest possible on steam turbines, 28.5 to 29 ins. or higher.

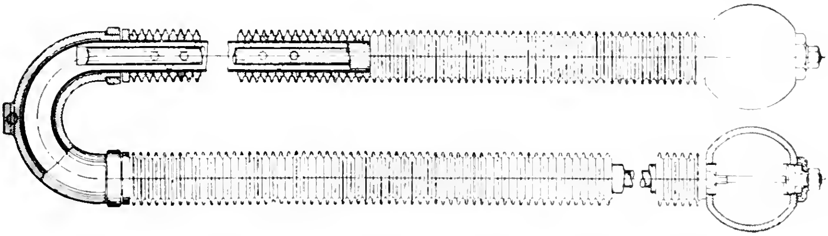


FIG. 10. FOSTER SUPERHEATER — DETAIL OF ONE ELEMENT.

You can save approximately one per cent. of coal for each eleven degrees fahr. that you can raise the feed-water temperature from waste products such as escaping exhaust steam or flue gases, neglecting the cost doing it. So if your feed water is going to the boilers at materially less than 212 degrees, and any steam is being wasted, it would be well to set it at work. If this steam is clean, or contains only a small amount of oil, an open heater (Fig. 7) where the steam and water are brought into intimate contact will give the best results, as all the heat is utilized and the water of condensation is saved.

If the exhaust steam contains much oil or other harmful elements, a closed heater (Fig. 8) is better, as the water and steam are kept separate. Then the water of condensation together with the heat in it are lost. See that your heaters are kept clean, as scale will materially interfere with their heating ability.

Economizers (Fig. 9) are closed heaters for utilizing the

waste heat of the flue gases for heating the feed water. They are rather bulky, and often require induced draft fans to assist the stack, as they cause considerable friction to the passage of the gases, and the lowered temperature of the gases reduces the capacity of the chimney. However, where coal is very expensive or there is not exhaust steam enough to heat the feed water, they are of advantage. When high boiler pressures are used, resulting in high flue gas temperatures, economizers show large savings. In existing plants where boilers are poorly designed and have to work at heavy overloads, it might be cheaper to gain capacity by installing an economizer rather than building an extension.

Superheaters (Fig. 10) are either separately fired or are included in the boiler setting. Superheating the steam may produce marked economies in any plant using saturated steam. Each plant, however, should be studied before deciding on the amount to be used and the cost of doing it.

High degrees of superheat are only to be attempted in plants specially designed for it.

Gebhardt, in "Steam Power Plant Engineering," gives for moderate superheating, — that is 100 degrees to 125 degrees fahr., — continuous operation, a fair average reduction of steam per horse-power of:

1. Slow running, full stroke, or throttling engines including pumps, 40 per cent.
2. Simple engines, non-condensing, with medium piston speeds. . . 20 per cent.
3. Compound condensing Corliss engines. . . . . 10 per cent.
4. Triple expansion engines. . . . . 6 per cent.

In turbine practice, each ten degrees of superheat usually lowers the water rate one per cent.

Some plants are called upon to carry very heavy overloads for a short time, either periodically or occasionally. Forced draft will often save fuel and money in those cases. If these periods are fairly often, it would be better to install the more expensive fan equipment, as that will only use two per cent. to four per cent. of the steam; but if these occasions are very infrequent it is cheaper to install a steam air injector that may use from five per cent. to ten per cent. of the steam or more. The standby losses of boilers, such as banking, are considerable,

and if boilers have to be kept banked for long periods to cover a few emergencies, auxiliary forced draft will be found advantageous.

The steam loop is a simple means of returning the condensation in piping to the boiler, and is adequate for small stations. In plants of several units, however, it does not work so well, and Holly drip return system may be used. By these means all high-pressure drips are saved and the bleeder steam from the nozzle in the upper tank can be put into the feed water heater and the heat saved. The exact saving depends on the men operating the plant and what wastage of steam would be allowed from drips if the automatic arrangement were not used.

DISCUSSION.

ALFRED O. DOANE.* — It has occurred to me that it might be well to speak of an economy that might be effected by using a mixed fuel which Mr. Parker has not touched upon. Perhaps it is impractical to use it in his station, but in our stations we have had very good success and found that it has relieved the difficulties in this trying period of coal shortage. We mix various sorts of small anthracite in proportions that we have found economical and practical. We do not use water-tube boilers. Our largest boilers are of the Deane type, with vertical tubes, and we have always made it a practice to burn a certain percentage of screenings and small-sized anthracite, — finding it advantageous from two or three standpoints. We can generally realize a small saving in dollars and cents in addition to securing a smokeless operation. During this coal shortage we have made an attempt to burn still larger proportions of anthracite and the limit of our operations seems to be the draft available, and as we use economizers the draft is somewhat cut down, from causes that Mr. Parker has stated. We have put in some blowers very much like automobile fans, and by these, making a slightly increased pressure under the grate, we have been able to burn a considerable proportion of fine anthracite, resulting in some saving of coal. We have found, however, that there are some precautions to take, especially when using a vertical tube

* Division Engineer, Mass. Metropolitan Water and Sewerage Board.

boiler which is very sensitive to undue heat on the ends of the tubes. The water may be driven away from the tube sheet, causing the ends of the tube to burn, and holes in the fire may result. But by putting in about one-quarter inch air spaces, the trouble is largely obviated so that we can burn about eighty per cent. of this fine coal with advantage. With natural draft we have found the limit of efficiency to be about fifty per cent. or sixty per cent. The trouble seems to be that while you can burn a large portion, there are losses due to two causes. First, with too large a proportion of fine coal much will sift through the grate and be lost in the ashes. Second, lack of draft causes imperfect combustion, as it is impossible to get oxygen enough through the fire to burn the fuel efficiently. We have found economizers advantageous, as most of our main units, the air pump and feed pumps, are driven directly from reciprocating parts of the machinery so that we have practically no heat from auxiliaries for the feed water. The economizer takes care of that, and also affords a settling chamber for a very considerable amount of dirt and scale-forming material which might otherwise reach the boiler. The matter of measuring feed water may be mentioned. As we use reciprocating engines, etc., we do not consider it safe to put water that has a suspicion of oil into our boilers, especially as the type of oil we use is very sensitive to that sort of thing. So we have to use closed heaters, and in most of our plants the water has to be measured after it has been heated to some extent. We have had much trouble trying to find a satisfactory hot-water meter. It is impossible to use rubber disks and all metal disks wear rapidly and give out. Finally, we got some Venturi meters which have given very excellent satisfaction, but are expensive, — especially the registers, — so that for most small plants they would probably not be feasible. I would like to emphasize particularly one of the points that Mr. Parker brought out, and that is to take care of the settings of any brick set boilers, to be sure there is no leakage of air, which will greatly cut down the economy. This is something that has to be followed up constantly, as cracks which open and close, and often are almost invisible will let in a surprising amount of cold air.

Frank B. Sanborn.* — We ought to thank Mr. Parker for allowing us to visit his plant. I am sure all who visited it and all who have heard Mr. Parker have been impressed with the opportunities for study that exist there and the splendid developments they are making at that plant. I have one or two questions I would like to ask Mr. Parker. One is concerning the means for measuring the feed water. Mr. Doane spoke of the Venturi meter, while the speaker showed a triangular meter. I wondered if the triangular meter would not cost a good deal less and still give pretty nearly as good efficiency.

Mr. Parker. — There are several kinds of weirs being used with great success. One is the V notch and the other is a particular curve. I have forgotten just what it is now, but it is curved down to a point so that equal increments of rise give equal increments of water flow, so that a recording chart can be very easily placed on one of those meters. There is also another type of meter which consists of buckets that will hold a thousand pounds of water, for instance. Water flows into them, and when it fills this bucket it is dumped over and you get a certain volume of water at the temperature of the feed water, and it is recorded right there. You can get an indicating meter which is not very expensive. They have a lot of apparatus to-day for measuring fairly hot water that are not very expensive. The hot-water meter of the old-fashioned type is no use at all after a short time.

Mr. Doane.—I perhaps did not make it clear enough that we are under the necessity of using closed feed-water heaters with the water under pressure, so that we are not able to use any of these notch segments. It is the Venturi register, of course, that is the expensive thing; but unless you have the register it is almost impossible to keep track of the flow with an indicator or anything of that kind. There was one experience we had with Venturi meters which may be of interest. That was that our very long single-action feed pump developed a high vibration and kick in the pipe, which the ordinary air chambers did not seem to take care of, but we devised, after considerable trouble, a very large air chamber in which the

* Professor of Civil Engineering, Tufts College, Mass.

water was taken through in a certain way that practically obviated the trouble and made the Venturi register act very much better, as it almost entirely stopped any vibration of the pen arm of the meter. If you have considerable vibration, it is practically impossible to get correct measurements with the Venturi meter.

Frank A. Marston.* — An interesting example of the installation of an undergrate draft apparatus to economize in the cost of fuel, was recently brought to the writer's attention at Canton, N. Y. For the following information credit is due Mr. L. R. Smith, superintendent of the Canton Water Works.

The apparatus installed is a steam-turbine driven, propeller fan, automatically controlled by the steam pressure acting on a balanced valve which also controls a damper regulator. It was manufactured by the Coppus Engineering and Equipment Company, of Worcester, Mass. The level arm of the damper regulator is connected to the damper and to the lever attached to the balanced valve controlling the supply of steam delivered to the turbo blower, so that when the regulator closes the damper it also shuts the balanced valve, cutting off the steam supply to the blower and thus reducing or stopping the undergrate draft. As long as the steam stays at the desired pressure, the blower does not operate. When the steam pressure falls below the required amount, the damper and the balanced valve both open, the blower starts the draft, and the steam pressure is brought back to the desired point. The blower is then shut down and the damper closed, as first described.

The cost of the apparatus installed complete was about $225. Information is not available for an exact statement of the fuel economy, but a general idea of the results can be gained from the following notes.

When the blower was installed, two or three years ago, about forty net tons of three-quarter lump bituminous coal were burned per month. After installing the blower, a mixture of 75 per cent. anthracite yard screenings and 25 per cent. three-quarter lump bituminous coal was burned, requiring 10 per

* Designing Engineer, with Metcalf & Eddy, 14 Beacon Street, Boston, Mass.

cent. more coal in total quantity. The conditions as to pumping were substantially the same.

At the present time (February, 1918), three-quarter lump bituminous coal costs $8.00 per ton and anthracite yard screenings $3.00 per ton (2 000 lbs.). On this basis the saving amounts to about one hundred dollars per month.

The labor of firing the boilers is somewhat easier, even though the quantity to be handled is greater. There are two return tubular boilers of 85 h.p. each, hand stoked. The steam pressure is maintained at from 90 to 100 lbs. per sq. in.

No additional wear on the boilers has been noticed, although it may be that there is greater depreciation because of the increased draft. The apparatus is rather noisy, which for some locations might be objectionable.

MEMOIR OF DECEASED MEMBER.

ALBERT SEWARD GLOVER.*

Born April 6, 1855. Died April 23, 1917.

ALBERT S. GLOVER was born at South Boston on the date noted above. His father was Albert Henry Glover, originally of Ipswich, Mass., and his mother was Mary Ann Wilson, of Salem. His parents moved to Cottage Farm when he was a young boy, and to West Newton in 1864. For many years Mr. Glover's father was master builder for the Boston & Albany Railroad, having charge of the construction of various wooden bridges and buildings, some of them very large.

Albert S. Glover attended the Newton High School, where he was a leader in athletics, particularly in baseball and football. He was graduated in 1873, being a classmate of John A. Gould. In the fall of that year he entered the Massachusetts Institute of Technology with the class of 1877, having as classmates Prof. George F. Swain, Richard A. Hale, Henry H. Carter, Joseph P. Gray, Charles F. Lawton, George W. Kittredge, the late E. H. Gowing, and other well-known engineers.

In 1875, when work on the Sudbury Water Works for the City of Boston was actively begun, Mr. Glover left the Institute and took a position on the engineering force, being associated with Frederic P. Stearns, George S. Rice, Wilbur F. Learned, and others. A little later he was assigned by the engineer, Mr. Alphonse Fteley, to act as his secretary, and as assistant to the paymaster and purchasing agent; and in 1879 he became paymaster and purchasing agent. In July, 1879, he was elected water registrar of the City of Newton — the executive officer of

* Memoir prepared by Richard A. Hale and Charles W. Sherman and taken largely from the very complete memoir published in the Journal of the New England Water Works for June, 1917.

the Water Department — and held that position until January 1, 1890, when he resigned to become secretary of the Hersey Manufacturing Company, having charge of sales of Hersey meters in New England. To this work he devoted the remainder of his life. He was also clerk of the Common Council of Newton from 1882 to 1887.

Mr. Glover was married, on September 21, 1875, to Mary Wales Robinson, of Newton, who survives him, with their daughter, Mary Wales Glover, a graduate of Smith College.

He was a member of the following societies and clubs, in addition to the Boston Society of Civil Engineers, American Water Works Association, New England Water Works Association, Newton Club, Boston City Club, Engineers Club, Hunnewell Club, Middlesex Club, Economic Club, Bostonian Society, Brae Burn Country Club, Tedesco Country Club. He became a member of the Boston Society of Civil Engineers on June 17, 1885.

Vol. V MAY, 1918 No. 5

BOSTON SOCIETY OF CIVIL ENGINEERS

FOUNDED 1848

PROCEEDINGS

PAPERS IN THIS NUMBER.

"Some Features of New York City's Rapid Transit System." Robert Ridgway.

Memoir of Deceased Member.

Contributors are hereby notified that proof will not be submitted to them for examination unless requested before the 10th of the month preceding the month of publication.

SANITARY SECTION EXCURSION TO WORCESTER, June 5, 1918.

Members of the Boston Society of Civil Engineers are invited by the Officials of the City of Worcester, to inspect the Worcester Sewage Purification Works and Experimental Activated Sludge Plant, on June 5, 1918.

The party will leave South Station at 12 M. on Track 13. Special badges of identification will be distributed to the members as they enter the gate. At Union Station in Worcester a special trolley car will be provided by our hosts, which will take us to Greenwood Park, overlooking the Purification Works. Here we shall be entertained at lunch by the City Officials. After a short business meeting, Mr. Matthew Gault, Superintendent of the Sewer Department, will give us a brief account of Worces-

ter's Sewage Disposal Problem, and Mr. Roy J. Lanphear, Chemist-in-Charge of the Purification Works, will describe the tests being carried out with the Experimental Activated Sludge Plant. Opportunity will then be afforded to inspect the Works. Members may return to Boston either by train or by the Boston & Worcester trolley express. Trains leave Worcester at 4.58, 5.05 and 6.17; trolley express leaves Worcester City Hall on the hour and half hour. Fare by train, $1.12; fare by trolley, $0.77.

This excursion will afford an opportunity for us to see in operation not only the older methods of Chemical Precipitation and Sand Filtration, but also the latest development in the art of sewage treatment, known as the Activated Sludge Process. By this process the strong, highly-colored sewage of the city is rendered clear and sparkling. No member who desires to keep in touch with the progress of Sanitary Engineering can afford to miss this opportunity. Send in your reply card promptly and let us show our appreciation of the generous invitation of the Worcester Officials by a large attendance.

ALMON L. FALES, *Chairman.*
HENRY A. VARNEY, *Clerk.*

MINUTES OF MEETING.

BOSTON, April 17, 1918. — A regular meeting of the Boston Society of Civil Engineers was held this evening at Chipman Hall, Tremont Temple, and was called to order by the President, Charles M. Spofford, at 8 o'clock.

There were 75 members and visitors present.

The records of the special meeting of February 27 and the annual meeting of March 20, 1918, were read and approved.

The Secretary reported for the Board of Government the election of the following to membership in the grades named:

Members — Messrs. Leroy G. Brackett, Max Silverman and Earl Stafford.

Juniors — Messrs. Benjamin H. Kerstein and Harry A. Wansker.

Associate — Mr. Rufus R. Moore.

The Secretary announced that, under authority of a vote passed at the annual meeting, the Board of Government had appointed the following committees:

On the Library: S. Everett Tinkham, Frederic I. Winslow and Henry F. Bryant.

On Publication: Charles W. Sherman, John L. Howard and Edwin H. Rogers.

On Papers and Program: Charles M. Spofford, chairman *ex officio;* Harrison W. Hayward, Angus B. MacMillan, Harry E. Sawtell, Frank C. Shepherd, S. Everett Tinkham and Robert Spurr Weston.

On Social Activities: David A. Ambrose, William W. Bigelow, John B. Babcock, 3d, Charles R. Berry, Royall D. Bradbury, Samuel P. Waldron and Luis G. Morphy.

On Membership: Harry F. Sawtelle, Rufus M. Whittet and Henry C. Robbins.

The Secretary presented a memoir of Charles Webster Gay, prepared by a committee consisting of William L. Vennard and Frank B. Rowell, and by vote it was accepted and ordered printed in the JOURNAL.

The following vote passed at the annual meeting of the Society was again passed by a unanimous vote, as required by the By-Laws:

Voted, that the dues for the year 1918–19 be abated to all members in the military or naval service of the United States or its allies; and that a sum not exceeding one thousand dollars be appropriated from the income of the Permanent Fund to reimburse the Current Fund of the Society for the resulting loss.

The President then introduced Commander H. R. Stanford, Civil Engineer, U. S. N., who gave an illustrated talk on the construction of the Pearl Harbor Dry Dock at Hawaii. A short discussion followed the talk, in which Mr. Hodgdon, Mr. FitzGerald and Commander Stanford took part.

After passing a vote of thanks to Commander Stanford for his courtesy in coming before the Society and giving so interesting and instructive a description of this important work, at 9.30 o'clock the meeting was adjourned.

S. E. TINKHAM, *Secretary.*

APPLICATIONS FOR MEMBERSHIP.

[May 4, 1918.]

THE By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of twenty (20) days from the date given.

ARONSON, MARK, Boston, Mass. (Age 23, b. Boston, Mass.) Graduate of Mechanic Arts High School, Boston, 1912; graduate of Mass. Inst. of Technology, 1916, civil engineering course, degree of S.B. Is with Dept. of Mechanical Design, U. S. Navy Yard, Boston. Refers to C. B. Breed, H. J. Hughes, C. M. Spofford and H. A. Wansker.

FEAR, HOLBERT WHITE, Cambridge, Mass. (Age 27, b. Gloversville, N. Y.) Graduate of Cornell University, 1913, degree of C.E. For one year immediately following graduation, chainman, rodman and transitman on Barge Canal construction, with Dept. of New York State Engineer and Surveyor; from July, 1914, to date, with U. S. Geological Survey, Water Resources Branch, serving until August, 1917, as junior engr., in which capacity he was employed at Albany, N. Y., on investigation of surface waters of New York and New England, collecting base data, making current meter discharge measurements, etc.; at Washington, D. C., on preparation of water-supply papers; at Boston in charge of office computations of discharge of New England streams; and at Denver, Colo., on similar work; in August, 1917, was promoted to assistant engr., and in November, 1917, returned from Denver to Boston office, where he is now in charge of entire office during absence of district engr. Refers to H. S. Boardman, R. A. Hale, C. H. Pierce, A. T. Safford, W. F. Uhl and D. M. Wood.

Hanna, John Baxter, Pawtucket, R. I. (Age 27, b. Pawtucket, R. I.) Graduate of Pawtucket High School. From September, 1909, to date, with City Engr.'s Dept., Pawtucket; has served as transitman, levelman, computer, draftsman and assistant engr. on sewer and highway construction. Elected a Junior January 27, 1915, and now desires to be transferred to grade of Member. Refers to G. A. Carpenter, E. S. Patton and F. A. Sweet.

Hoyt, Laurence Brackett, Melrose, Mass. (Age 26, b. Greenland, N. H.) Graduate of Mass. Inst. of Technology, 1913, civil engineering course, degree of S.B. During summer of 1911, rodman with Boston Elevated Ry. Co.; during summer of 1912, rodman with Power Construction Co., Hoosac Tunnel, Mass., and later rodman and instrumentman with Directors of Port of Boston; in 1913–14 assistant in civil engineering, Mass. Inst. of Technology, serving as instructor during summer of 1913 at surveying camp, E. Machias, Me.; while assistant at Mass. Inst. of Technology, did private work on computation and design in connection with bridge apportionment costs; from June, 1914, to date, resident engr. with Mass. Highway Comm. Elected a Junior November 19, 1913, and now desires to be transferred to grade of Member. Refers to C. F. Allen, C. B. Breed, R. W. Coburn, G. L. Hosmer, J. W. Howard and C. M. Spofford.

Snow, Benjamin Harrison, Everett, Mass. (Age 25, b. Everett, Mass.) Graduate in surveying and structural engineering courses, Northeastern College (Boston Y. M. C. A.) School of Engineering, 1917. From August, 1913, to April, 1914, transitman and inspector with Sterrett & Benners, at Boston Fish Pier; from May to September, 1914, transitman with Whitman & Howard, Boston; from October, 1914, to May, 1916, iron and steel draftsman with Babcock-Davis Corp'n, Cambridge, Mass.; from May, 1916, to date, structural designer with Industrial Service & Equipment Co., Boston. Elected a Junior September 20, 1916, and now desires to be transferred to grade of Member. Refers to B. S. Brown, E. W. Colby, C. S. Ell, H. A. Gray and Channing Howard.

Woodbury, Stanley Ward, Haverhill, Mass. (Age 27, b. Haverhill, Mass.) Graduate of Haverhill High School; has completed course in concrete construction at Boston Y. M. C. A. Evening School; has completed half of I. C. S. course in civil engineering. Has had eight years' experience, including four years on construction of highways and bridges, two years on surveying and about two years on drafting and estimating, all with Essex County Engineering Dept., with which Dept. he is still employed. Elected a Junior April 15, 1914, and now desires to be transferred to grade of Member. Refers to B. S. Brown, R. R. Evans, L. C. Lawton and A. D. Marble.

ROLL OF HONOR.*

ATWOOD, JOSHUA. Captain, Infantry, National Army, Headquarters Northeastern Dept., Boston, Mass.

BABBITT, JOHN H. 1st Lieutenant, C. A. C., U. S. A., commanding 31st Co., Coast Defenses of Narragansett Bay, Fort Adams, R. I.

BALCH, WILLIAM H. Captain, E. O. R. C., Am. Ex. Force, France.

BEARD, CORNELIUS. 1st Lieutenant, Company A, 101st Engrs., Am. Ex. Force, France.

BRESTH, ALEXANDER.

BROWN, H. WHITTEMORE. 2d Lieutenant, E. O. R. C., 301st Engrs., Camp Devens, Mass.

BROWN, WILLIAM AUGUSTINE. Machinist's Mate, 1st Class, U. S. N. R. F., Navy Yard, Boston, Mass.

† BRYANT, CHAUNCEY D. 1st-class Private, 101st Engrs., Am. Ex. Force.

BUNKER, PAGE S. Major, Ordnance, Dept. U. S. N. A., Augusta Arsenal, Augusta, Ga.

BURLEIGH, WILLARD G. Corporal, Company E, 25th Engrs., Camp Devens, Mass.

BUSSEY, BYRON C. 2d Lieutenant, E. O. R. C., Officers' Training Camp, Washington, D. C.

CLAPP, WILFRED A. Q. M. C.

CLARKSON, EDWARD H., Jr. Sanitary Engineer, American Field Ambulance.

COBURN, WILLIAM H. 1st Lieutenant, Field Supply Section, Gas Defense Service, New Interior Bldg., Washington, D. C.

COFFIN, S. P. 1st Lieutenant, Railway Transportation Corps, National Army.

CRAIGUE, JOSEPH S. Captain, Engrs., U. S. R., Gas Service, Am. Ex. Force.

CROSS, RALPH U. 1st-class Sergeant, Q. M. C., U. S. A., Headquarters Northeastern Dept., Boston, Mass.

CURTIS, GREELY S. Lieutenant (j. g.), Naval Militia, Mass.

DASHPER, FREDERICK C. With British Army.

DAVIS, HAROLD F. Supply Sergeant, 6th Reg't, Company A, Mass. Infantry, Am. Ex. Force, France.

DELANO, RAY O. Sergeant, Company B, 301st Engrs., Camp Devens, Mass.

DEMERRITT, ROBERT E. 2d Lieutenant, C. A. C., U. S. A., Fort Monroe, Va.

DEMING, GUY S. Captain, Construction Co. No. 12, Aviation Section, Signal Corps, U. S. A., Aviation Mobilization Depot, Camp Levier, Greenville, S. C.

DRUMMOND, WILLIAM W. Captain, Engrs., U. S. R., Camp Lee, Va.

DURHAM, HENRY W. Captain, Engrs., R. C., 20th Engrs., Camp American Univ., Washington, D. C.

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* This list is made up from replies to a circular sent out to members of the Society, and from various other sources. That future lists may be more accurate and complete, members are requested to call the attention of the Secretary to any inaccuracies or omissions.

† Died in France.

EDDY, HARRISON P., Jr. Assistant Naval Constructor, U. S. N. R. F., U. S. Navy Yard, Norfolk, Va.

ELKINS, CLAYTON R. Lieutenant, Public Works Dept., Navy Yard, Norfolk, Va.

ELLSWORTH, SAMUEL M. Company I, 3d Officers' Training Camp, Camp Upton, Long Island, N. Y.

ENEBUSKE, CARL C. 55th C. A. C.

FERNALD, GORDON H. 1st Lieutenant, E. O. R. C., 304th Engrs., Accotink, Va.

FOOTE, FRANCIS C. Lieutenant, 303d Engrs., E. O. R. C.

FRENCH, HEYWOOD S. Major, Q. M. C., National Army, 2521 University Place, Washington, D. C.

GERRISH, HERBERT T. 1st Lieutenant, Engr. R. C., E. R. O. T. C., Camp Lee, Va.

GIBLIN, JOHN F. A. 1st Lieutenant, 101st Engrs., Am. Ex. Force, France.

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PAPERS AND DISCUSSIONS

SOME FEATURES OF NEW YORK CITY'S NEW RAPID TRANSIT SYSTEM.

By Robert Ridgway.*

(Presented March 20, 1918.)

For the past ten years, New York City has been engaged in constructing a rapid transit system calculated to increase threefold the facilities which existed before any part of this new system was placed in operation. The work is being done under the direction of the City of New York through the Public Service Commission for the First District of the State of New York, which commission is charged by law with this duty in addition to its work of regulating public service corporations within the limits of the city of New York. The new system has become known as the "Dual System of Rapid Transit," because under two contracts, called "Contract No. 3" and "Contract No. 4," signed on March 19, 1913, it is provided that the new lines are to be operated by two transit companies. The Interborough Rapid Transit Company, under Contract No. 3, is to operate certain lines in the boroughs of Manhattan, The Bronx, Brooklyn and Queens, the new system being an extension of its present subway and elevated systems. Contract No. 4 was made with the New York Municipal Railway Corporation, formed for the purpose by the Brooklyn Rapid Transit Company, which controls the existing "L" lines in the borough of Brooklyn. The

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lines covered by Contract No. 4 are in the boroughs of Manhattan, Brooklyn and Queens, and will be operated for the New York Municipal Railway Corporation by the New York Consolidated Railroad Company. Thus all of the five boroughs of the city are provided for in the new program except the borough of Richmond (Staten Island), but a tentative plan has been made for a tunnel to be constructed some time in the future under the channel known as "The Narrows," connecting this borough with the Fourth Avenue subway in the borough of Brooklyn.

Under Contracts Nos. 3 and 4, while the companies contribute to the cost of construction, the city will own the structures except certain lines known as "Company lines," which are extensions of their existing railroads. The companies provide the equipment, which includes third rail, signal and lighting installations, rolling stock, power, transmission lines, etc. The estimated cost of construction is $342 000 000, and of equipment $81 000 000, not including $105 000 000 spent on account of the existing Interborough Rapid Transit subway. The cost of the "L" systems of that company and of the Brooklyn Rapid Transit Company is not included in these figures. The surface lines are not included in the contracts, though most of them are controlled by the Interborough Rapid Transit and Brooklyn Rapid Transit interests. The following table will be of interest as showing the distribution of estimated cost:

INTERBOROUGH RAPID TRANSIT SYSTEM.

City-Owned Lines (New).	City Money.	Company Money.	Total.
Construction	$86 000 000	$58 000 000	$144 000 000
Equipment	———	44 000 000	44 000 000
Total	$86 000 000	$102 000 000	$188 000 000
Company-Owned Lines (New).			
Construction	———	$29 000 000	$29 000 000
Equipment	———	11 000 000	11 000 000
Total	———	$40 000 000	$40 000 000
Total cost of new system (Contract No. 3)	$86 000 000	$142 000 000	$228 000 000

Cost of Existing City-Owned Subways and "L" Connections, Contracts 1 and 2.			
Construction	$59 000 000	$11 000 000	$70 000 000
Equipment	———	35 000 000	35 000 000
Total	$59 000 000	$46 000 000	$105 000 000
Total for I. R. T. system exclusive of existing Manhattan "L" lines and connections	$145 000 000	$188 000 000	$333 000 000

NEW YORK MUNICIPAL RAILWAY CORPORATION.

City-Owned Lines (New).	City Money.	Company Money.	Total.
Construction	$134 000 000	$14 000 000	$148 000 000
Equipment	———	20 000 000	20 000 000
Total	$134 000 000	$34 000 000	$168 000 000
Company-Owned Lines (New).			
Construction	———	$21 000 000	$21 000 000
Equipment	———	6 000 000	6 000 000
Total	———	$27 000 000	$27 000 000
Total for N. Y. M. System (Contract 4) exclusive of existing "L" lines of company	$134 000 000	$61 000 000	$195 000 000
Grand total for Dual System, exclusive of existing company-owned "L" lines	$279 000 000	$249 000 000	$528 000 000

TRACK MILEAGE IN DUAL SYSTEM.

Interborough Rapid Transit Company.

Existing subway (City owned) —

4-track structure, 7.5 miles, 30.0 running track miles.
3-track structure, 1.9 miles, 5.8 running track miles.
2-track structure, 9.8 miles, 19.6 running track miles.

Total . . . . . . 19.2 miles, 55.4 running track miles.

Existing "L" lines (City owned) —

6.2 miles, 17.6 running track miles.

New subway (City owned) —		
4-track structure,	11.7 miles,	47.7 running track miles.
3-track structure,	3.9 miles,	11.7 running track miles.
2-track structure,	8.8 miles,	18.7 running track miles.
New "L" (City owned) —		
3-track structure,	19.8 miles,	59.7 running track miles.
2-track structure,	4.1 miles,	9.2 running track miles.
New "L" extensions (Company owned)		
2-track structure,		11.1 running track miles.
New 3d Tracks on "L" (constructed by Company),		15.0 running track miles.
Total (new lines)........		246.1 running track miles.
Add existing "L" lines (Manhattan R. R. Co.).......		90.7
Total Interborough Rapid Transit...		336.8

NEW YORK MUNICIPAL RAILWAY CORPORATION.

New subway (City owned) —		
4-track structure,	11.2 miles,	46.5 running track miles.
2-track structure,	13.7 miles,	28.0 running track miles.
New "L" lines (City owned) —		
3-track structure,	9.2 miles,	27.6 running track miles.
2-track structure,	3.4 miles,	6.9 running track miles.
New "L" extensions (Company owned) Including C. I. Terminal and Sea Beach and Brighton reconstruction.........................		36.9 running track miles.
New 3d Tracks on "L" (Constructed by Company)		13.8 running track miles.
Manhattan Bridge (4 tracks)		5.2 running track miles.
* Total (new lines)....		164.9 running track miles.
Add existing "L" lines incorporated in new system........		107.0 running track miles.
Total N. Y. M. Ry. Corp.		271.9 running track miles.

* This includes only additional trackage in the case of reconstructed existing lines; for example, Sea Beach Line — 5 miles, existing 12 miles and as reconstructed 17 miles.

PERCENTAGE OF WORK DONE ON NEW SYSTEM.
(Construction and Equipment.)

	I. R. T.	N. Y. M.	Total.
Estimated total cost	\$228 000 000	\$195 000 000	\$423 000 000
Cost of work done	174 000 000	151 000 000	325 000 000
Ratio	76	77	77

MILEAGE — PERCENTAGE IN OPERATION IN NEW SYSTEM.

	I. R. T.	N. Y. M.	Total.
Total additional track miles to be provided	246	164	410
In operation	67	96	163
Ratio	26	58	40

The construction and equipment work called for by these contracts is practically 77 per cent. completed. The unfinished work is principally in the borough of Brooklyn, but also includes the Broadway-Seventh Avenue-60th Street line north of 42d Street, of the 14th Street crosstown line, part of which is in the borough of Manhattan; the four pairs of tunnels under the East River; and some odds and ends of other lines. Work on these unfinished contracts is in progress and is well advanced. The building of the proposed Nassau Street subway in lower Manhattan, connecting two tracks of the Center Street Loop at the station under the Municipal Building with the Whitehall Street-Montague Street East River tunnels, has been deferred for the present. Some of the new lines are now in full or partial operation. Of a total track mileage of 410 miles provided for in the new program, 163 miles are now being operated.

Mr. LeRoy T. Harkness, now chief of rapid transit for the Public Service Commission, took a leading part in the preparation of the Dual Contracts as assistant counsel for the commission, and no one is better informed regarding them than he. The following is quoted from his paper presented to the Municipal Engineers of the City of New York in November, 1913:

"The main points in the arrangement with the Interborough Company (Contract No. 3) were:

"1. The company agreed to equip the lines proposed for operation by it in the report of June 5, 1911, at an estimated expense of \$22 000 000, to

contribute $58 000 000 toward the construction, and when constructed and equipped, to maintain and operate such new lines for a term of forty-nine years in conjunction with the existing subway systems for a single five-cent fare.

"2. The leases of the existing subways (Contracts Nos. 1 and 2) were leveled so that the subways constructed under those contracts and the new subways will fall into the City's possession at one and the same time.

"3. The new lines are subject to recaption at the end of ten years, in accordance with the provisions of the Rapid Transit Act. This recaption may be exercised either directly by the City or through a new contractor. Provision was also made for exchanging part of the new subway lines for part of the old so that in the event of recaption the City may take over a complete east side or a complete west side line.

"4. The so-called Belmont Tunnel extending under 42d Street and the East River to the borough of Queens was turned in as part of the system at a valuation of $3 000 000.

"5. The receipts from existing and new subway lines are to be pooled, and from the gross receipts of both lines there is to be deducted and paid in the order named, deficits to be cumulative with compound interest:

"*a* Operating expenses; provision for depreciation, renewals and obsolescence; taxes, insurance and rentals payable to the City under existing subway contracts.

"*b*) A sum to be retained by the company amounting to $6 335 000 per annum, representing the average annual income received by it from the operation of the existing subway lines and equipment for the two fiscal years ending June 30, 1911.

"*c*) A sum to be retained by the company equal to six per cent. per annum upon the new investment of the Interborough Company in the new lines, estimated at $80 000 000, or $58 000 000 for new construction and $22 000 000 for new equipment.

"*d*) To be paid to the City the interest and sinking fund upon the bonds issued by the City for the construction of new lines, and in addition such further sum as will bring the payments to be made to the City up to an amount equal to 8.76 per cent. upon its expenditures.

"*e*) Any amount remaining to be divided equally between the City and the company, share and share alike.

"6. Future extensions required by the City may be added to the system and will be equipped and operated by the company as part of the entire system under a separate accounting system.

"7. The company at its own expense is to third track and extend the elevated lines leased by it from the Manhattan Railway Company.

"The main points in the arrangement with the Brooklyn Company (Contract No. 4), the contract being entered into with New York Municipal Railway Corporation, a company specially formed for the purpose, were:

"1. The company agreed to equip the lines proposed for operation by it in the report of June 5, 1911, to contribute $13 500 000 toward the con-

struction thereof, and when constructed and equipped, to maintain and operate such new lines for a term of forty-nine years in conjunction with the existing elevated railroad system of the New York Consolidated Railroad Company for a single 5-cent fare.

"2. The company to expend approximately $[illegible] in third-tracking and extending its existing lines.

"3. The new city lines and also the third tracks and extensions of the existing lines to be subject to recapture at the end of ten years in accordance with the provisions of the Rapid Transit Act. This recapture may be exercised either directly by the City or through a new contractor.

"4. The receipts from the existing system and the new subway lines to be pooled, and from the gross receipts of both lines there is to be deducted and paid in the order named, deficits to be cumulative:

"*a* Cost of operation which shall include operating expenses, taxes, rentals of leased property used in operation, and provision for depreciation and renewals.

"*b* A sum to be retained by the company amounting to $[illegible] per annum, representing the average annual income of the New York Consolidated Railroad Company from the operation of its existing lines.

"*c* A sum to be retained by the company equal to six per centum per annum upon the investment of the company in the new lines.

"*d* To be paid to the City interest and sinking fund charges upon bonds issued by the City.

"*e* Any amount remaining to be divided equally between the City and the company share and share alike.

"5. Future extensions required by the City to be added to the new city system, and will be equipped and operated by the company as part of the entire system under a separate accounting system."

The fare is five cents on each system, with no free transfers between them. No provision is made in the Dual Contracts for free transfers between the rapid transit and surface lines except at the 86th Street terminus of the Fourth Avenue subway in Brooklyn. There are, however, several points on the existing company-owned lines of the Brooklyn Rapid Transit system where free transfers are given between the "L" and surface lines.

When completed, one may ride a maximum distance of 27 miles and 23 miles on the Interborough Rapid Transit and New York Municipal Railway Corporation systems, respectively, for a single fare of five cents.

The foregoing is intended to give a general summary of the program of rapid transit for the greater city. Doubtless most

of you are familiar with many of the facts set forth, but the speaker has thought best to state them here, since it is found that even in New York, the community most deeply concerned, the significance of the changes in travel to be brought about by the inauguration of the new systems is not yet fully appreciated. It is not the purpose of the speaker to enlarge on the general scheme of operation, to analyze the plan, or to predict the effect of the greater transportation facilities on the community, socially or otherwise. It is thought that a description of some of the features of construction will be more interesting, since, due to his position with the commission, this phase of the work has been more specially under his observation.

Generally speaking, the construction scheme followed has been to build subways under the streets in the borough of Manhattan and in the congested sections of the other boroughs, and elevated structures (Fig. 1) in the less congested sections and in the outlying districts. Parts of three of the company-owned lines of the Brooklyn Rapid Transit Company in South Brooklyn, viz., the Brighton Beach, the Culver and the Sea Beach lines, are in open cuts without cover on the company's rights of way. They have been largely reconstructed and improved in connection with the new development. On Queens Boulevard, a highway of 200 ft. proposed width in the borough of that name, it was decided to substitute an ornamental reinforced concrete viaduct for the ordinary type of steel elevated structure. This problem was treated successfully by the designers and the commission's architect, Mr. Squire J. Vickers. (Fig. 2.) Where stations are located on elevated railroads at crossings of parkways, the steel members of the structures are enclosed in concrete, the faces of which are tooled and decorated with colored tile. (Fig. 3.)

While one usually thinks of a subway as of the standard-type structure seen from station platforms, the local conditions require many variations from this type. The standard four-track subway design (Fig. 4) requires steel bents spaced 5 ft. apart center to center, each bent consisting of two I-beam side columns, an I-beam roof girder, and three interior columns separating the track ways. "Jack" arches of concrete fill the spaces between

FIG. 1. TYPICAL STEEL ELEVATED STRUCTURE IN UNDEVELOPED SECTION.

FIG. 2. QUEENS BOULEVARD ELEVATED LINE TO CORONA IN THE BOROUGH OF QUEENS.

the side wall columns and between the roof beams, and concrete curtain walls, as a part of the ventilation scheme, fill the spaces

FIG. 3. STATION AT MOSHOLU PARKWAY ON JEROME AVENUE ELEVATED LINE, SHOWING TYPICAL TREATMENT WHEN PARKWAYS ARE CROSSED.

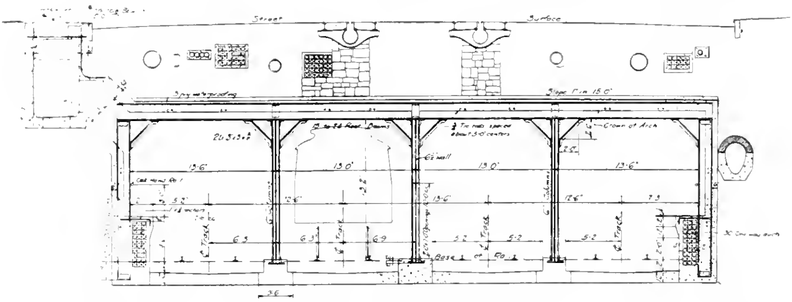

FIG. 4. SECTION OF TYPICAL FOUR-TRACK SUBWAY FOR INTERBOROUGH RAPID TRANSIT OPERATION.

between the columns on the center line. In this center wall, openings for manways are left every 10 ft. Where crossovers are necessary, one or more lines of interior columns are omitted

and the roof construction is made deeper on account of the longer span of the girders. The track centers are 12 ft. 6 ins. and 13 ft. 6 ins. apart minimum, in the I. R. T. and N. Y. M. structures, respectively, the one foot difference being due to the fact that the N. Y. M. car is 10 ft. wide, while the I. R. T. car is 9 ft. wide. The vertical distance from base of rail to under side of roof is 13 ft. 2 ins. minimum in both structures. Reinforced concrete in place of the steel bent type has been used for some of the subways, notably for the Center Street loop in Manhattan and the Fourth Avenue Subway in Brooklyn, as well as for the Brooklyn portion of the existing Interborough Rapid Transit subway. The steel bent type, however, is generally preferred by the constructors, not only because it is more convenient to erect, but it makes for safety in construction, as, when the steel frame is erected, the side and vertical loads of the trench can be transferred to it without waiting for all of the concrete to be placed between the bents. In the case of the reinforced concrete structure, the concrete must be allowed sufficient time to harden before it is permitted to take such loads.

When above ground-water level, subdrains are usually placed beneath the track floor. In the original subway, banks of 4-way ducts to carry the power cables were laid up against the outside of each side wall. In the new subway these ducts are laid inside of the subway structure against the side walls, and are enclosed in a concrete bench that will form a walk for passengers in case of an accident in the tunnel. A hand rail is attached to the side wall at a suitable elevation above the bench. About midway between stations an emergency exit to the street is provided, as well as a fan chamber and ample openings leading to gratings in the sidewalks just back of the curb lines. Similar ventilating openings at the approach to each station provide outlets for the air for the purpose of reducing its velocity on the station platforms in front of incoming trains. At low points in the grade, where the drainage will not automatically flow into the sewers, provision is made for sumps and automatic pumps to take care of seepage. In the first subway, the structure was completely waterproofed, generally with an envelope

of asphalt and felt, but in special cases with brick in asphalt mastic. In the new structures the waterproofing has been omitted where the conditions would warrant it, in the interest of economy and because it was believed that the omission would assist in lowering the temperature of the air in the subway by facilitating the radiation of heat through the walls and roof. Such parts of the structure as are below the ground-water level are waterproofed with fabric and coal-tar pitch, or with brick laid in asphalt mastic. It is also the practice to waterproof the roof of the structure at stations with brick in asphalt mastic and between stations with fabric and coal-tar pitch unless the roof is below the level of ground water, in which case brick in mastic is used.

From what has been said it will appear that the development of the subway design during the past fifteen years or more has resulted in a much more complicated structure than the original type, principally due to larger stations with increased facilities and additional provisions for ventilation.

Under Lexington Avenue, in width 75 ft. between building lines, the new subway is built from 43d Street to the Harlem River (about 132d Street) generally as a two-level structure, the local tracks on top following for the most part the grade of the avenue, while the express tracks are below, often in a tunnel, separated from the local tracks above by 10 to 55 ft. of ground. Between 79th and 99th streets the four tracks are in one structure with two local tracks immediately over the two express tracks. For a good part of this distance the structure is built in a rock tunnel, excavated with a cross-section 31 ft. 8 ins. wide by 32 ft. 7 ins. high. At 96th Street an additional width was required in the tunnel, for the platforms of the station for the upper or local tracks. At 99th Street the upper tracks diverge, going north until they clear the roof of the lower tracks, descending thence, relatively to the grade of the lower tracks, until near 103d Street the four tracks are abreast in a rock tunnel. The difficulty of constructing a tunnel of the large and varying cross-section required in the treacherous rock that was encountered in places will be readily appreciated by those experienced in such work. A paper read by Mr. I. V. Werbin, then assistant division en-

gineer for the commission, to the American Society of Civil Engineers, in September, 1916, treats of the difficulties encountered in the construction in an interesting and exhaustive manner. For the half mile north of 103d Street the subway was built by the cut-and-cover method, largely in water-bearing sand below tide level. From 113th Street north to the Harlem River the structure is a particularly complicated one, the tracks flexing in such a way as to come into the two level express station at 125th Street so that the northbound trains, both express and local, are at the upper level, while the southbound trains are at the lower level, thus reducing to a minimum the climb for the homeward or northbound passengers. Just north of the Harlem River the four-track subway divides into two three-track branches, and the flexing of the tracks above described is for the purpose of separating the east branch trains from the west branch trains without a grade crossing. This design required a trench in rock and in water-bearing sand of a depth of over 60 ft. below the street level at the approach to the Harlem River crossing. This long, deep cut, taking practically the whole width of the street, was a particularly impressive sight, and the methods adopted by the contractor for supporting the street loads, including the two electric surface railroad tracks, by means of well-designed timber towers, were very interesting and ingenious and were described in a paper presented to the American Society of Civil Engineers on February 16, 1916, by A. B. Lueder, M. Am. Soc. C. E., and W. J. R. Wilson, the contractor's general superintendent and engineer, respectively.

The Harlem River is crossed by means of a four-track subaqueous tunnel constructed by somewhat the same methods as were used for building the tunnel of the Michigan Central Railroad under the Detroit River. The Harlem River tunnel consists of four steel tubes, 19 ft. internal diameters, the interior walls having flat sides. They were fastened together on their flat sides. At intervals of 15 ft. 7 ins. were transverse steel diaphragms which extended out to the limits of the concrete envelope. The tubes were enclosed in concrete deposited by the tremie method, after the steel shells were sunk in place, forming a structure 76 ft. wide by 24 ft. 6 ins. high. The tubes

are lined with a concrete ring 15 ins. thick except on the flat sides, where it is 12 ins. thick reinforced. The bidders on this contract were given the opportunity of bidding on one, two or three designs, two of the cast-iron shell form, the third of the steel shell form above described. The lowest bid received was for the latter type, and the contract was awarded to the low bidder, Arthur McMullen and Hoff Company. Mr. Hoff, having been associated with the work on the Detroit River tunnel, was exceptionally well qualified to undertake the task of building the Harlem River Tunnel. The contract included not only the subaqueous tunnel 1 080 ft. long, but the north and south approaches as well. The bid price was \$3 889 775.05, of which \$1 620 000 was for the 1 080 lin. ft. of subaqueous tunnel, i. e., at the rate of \$1 500 per linear foot of four-track tunnel complete and ready for track. The width of the channel of the Harlem River from bulkhead to bulkhead measured on the center line of the structure was 600 ft. Therefore the subaqueous tunnel extended a considerable distance inland from the bulkheads, which were necessarily removed during construction and restored afterwards. The Harlem River is a tidal stream, and in order to comply with the requirements of the War Department permit, the top of the structure was placed at a minimum depth of 25.33 ft. below m.h.w., and the bottom was, therefore, 24.5 ft. lower, the greatest depth being about 57 feet below m.h.w. As the original river bed was about 7 ft. above the grade of the top of the tunnel, a considerable amount of dredging was required, mostly in mud and sand, but partly in rock. Approximately 275 000 cu. yds., barge measurement, were dredged for the purpose.

The steel shells were built in five sections in a yard on the Bronx side of the Harlem River, about a mile northwest of the site of the tunnel, somewhat as a steel ship is built. One of the sections was 200 ft. in length; each of the other four was 220 ft. in length. Each section included four tubes with connecting diaphragms. To the latter and to intermediate struts were attached the 4 in. x 12 in. horizontal lagging which acted as a concrete form. The cross-section, as before stated, was 76 ft. in width inside of the 4 in. lagging by 24 ft. 6 ins. high from bottom

to top of diaphragms. Bulkheads were placed in each tube near the ends, carried in every case above the flotation line. As each section was ready for launching, nine canal boats were floated at low tide under it, the rise of the tide lifting the structure off the stringers on which it was built. Tugs pulled the section out into the channel. The canal boats were scuttled and pulled from under, leaving the "sea-going tunnel" riding on the stream. (Fig. 5.) It was towed by tugs to the site of

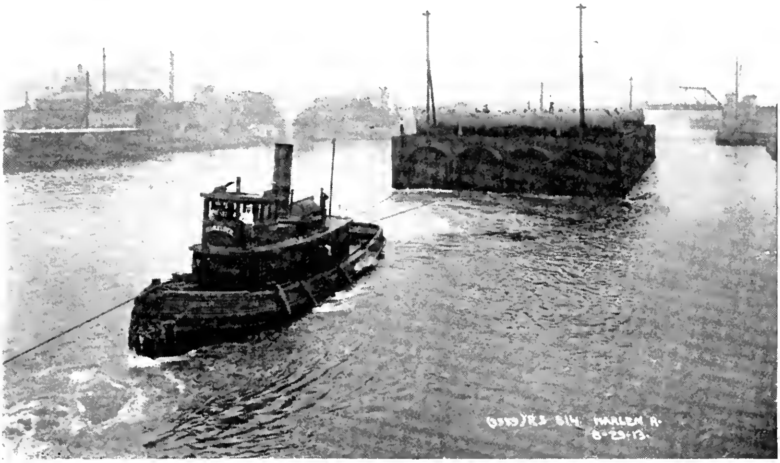

FIG. 5. TOWING A SECTION OF THE FOUR-TRACK HARLEM RIVER TUNNEL.

the tunnel, a time being selected so that the tide was running slightly against it, this providing better steerage. It was necessary to pass through three drawbridges on the way, — rather a delicate operation. Arrived at the site, the tubes were flooded and sunk into place. (Fig. 6.) Four steel buoyancy cylinders 10 ft. 6 ins. diameter and 68 ft. 3 ins. long, provided with the necessary valves and fittings, were attached transversely to the top of the structure, two cylinders near each end, and assisted in controlling the sinking. Each 220-ft. section weighed when afloat

with its equipment about 750 tons. Masts supporting line and grade targets attached to each end of the section afforded means of accurately adjusting the structure to its vertical and horizontal positions. After this was accomplished, the space below the bottom of the diaphragms caused by overdredging was filled with lean concrete by the tremie method. Then each pocket formed by the diaphragms and the side lagging was filled in one operation, by the same method, with 1 : 3 : 6 concrete. When

FIG. 6. SINKING A SECTION OF THE FOUR-TRACK HARLEM RIVER TUNNEL.

four of the five sections had thus been placed and enveloped with concrete, the tubes were pumped out between heavy bulkheads placed in the ends, and the interior ring of 1 : 2 : 4 concrete reinforced on the flat vertical sides was placed under normal air pressure. Subsequently the fifth section was completed in a similar manner. Connections to the land sections were afterwards made by means of cofferdams. The leakage into this subaqueous tunnel is practically negligible, and the speaker understands that it is less than that of any other transportation

tunnel now in use under New York waters. An evening could be devoted to a description of this tunnel, and for those interested in it the speaker would refer to a paper ably prepared by Mr. Howard B. Gates, assistant engineer in charge of the work, published in the 1915 Proceedings of the Municipal Engineers of New York City. The speaker cannot speak too highly of the manner in which the contractor carried out this large con-

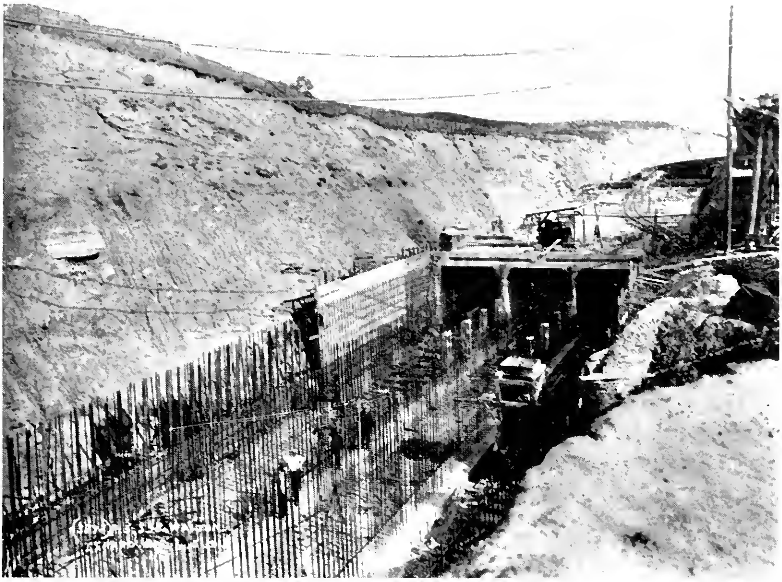

FIG. 7. LEXINGTON AVENUE LINE WHERE IT PASSES THROUGH FRANZ SIGEL PARK IN THE BOROUGH OF THE BRONX.

tract, and particular mention should be made of the work of Mr. Olaf Hoff and of the general superintendent, Mr. N. R. Melvin, a natural-born engineer, possessed of great ability and foresight. The accurate fitting together of all parts of this complicated work, its excellent workmanship and the entire absence of serious accidents during construction is due in large part to these two men.

North of the Harlem River the subway branches into two three-track lines as before stated, which come out of the ground

on to elevated structures beyond the more thickly settled districts. The west side, or Jerome Avenue branch, passes under Franz Sigel Park in a reinforced concrete structure before emerging from the ground. (Fig. 7.)

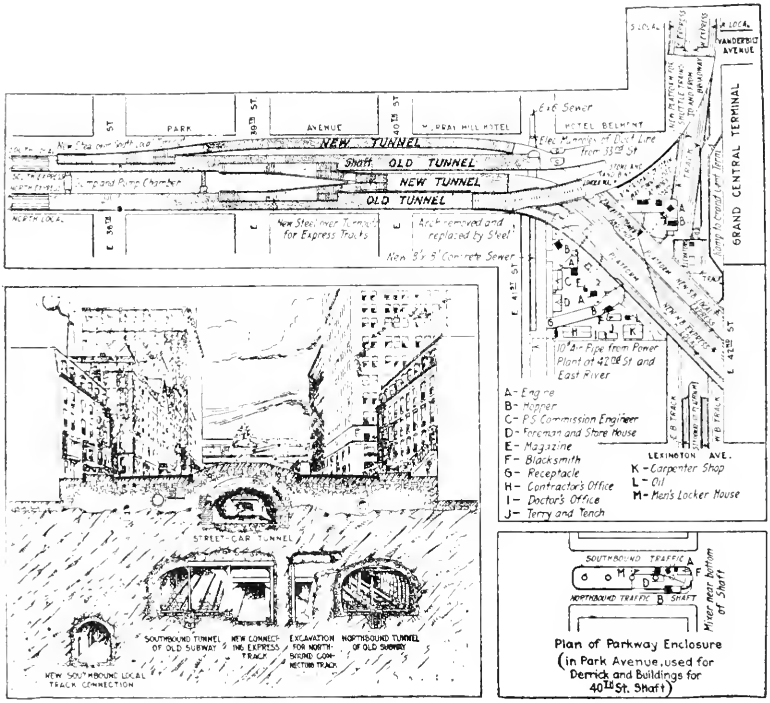

FIG. 8. CONDITIONS AT CORNER OF LEXINGTON AVENUE AND PARK AVENUE NEAR THE GRAND CENTRAL TERMINAL.

One of the most complicated and difficult problems presented to the designers and contractors of the Dual System was the connection between the new Lexington Avenue subway and the existing subway under Park Avenue in the vicinity of the Grand Central Terminal at 42d Street. (Fig. 8.) Both of these subways have four tracks, and those of the existing subway at the points of connection are in two double-track, concrete-lined rock tunnels. The operation of the existing subway, involving the

handling of over a million passengers daily and the passing of a train on one of the four tracks during rush hours about every thirty seconds, could not be interrupted. The work had to be carried on with due regard to this operation and with safety as the first consideration. For these reasons and because of the limited space inside of the operating subway, the work of demolition and construction was necessarily done from the outside of the old structure. It was provided that no tracks should cross at grade. Briefly, the design provided for taking the two express tracks out of the present tunnels at a point near 39th Street and bringing them into a new rock tunnel located between the existing tunnels, the new tunnel descending on a 2.5 per cent. grade until it is low enough to pass under the present northbound tunnel, when it curves to the east and emerges into the open cut on the site of the Old Grand Union Hotel between 41st and 42d streets. Similarly, the southbound local tracks are taken out of the old structure near 38th Street into a single-track rock tunnel extending north under the west sidewalk of Park Avenue, and descends until it can pass under both of the present tunnels, when it curves east also into the Grand Union site. The new northbound local track descends from a point between 40th and 41st streets, keeping its present alignment until it, too, curves into the same property. As an indication of the difficulties of the mining operations involved, a cross-section of Park Avenue near 40th Street now shows four double-track tunnels and one single-track tunnel, one double-track tunnel for the surface car operation, two for the present Interborough Rapid Transit operation, one for the new express operation, and the single-track tunnel for the new southbound local operation.

Through the Grand Union property, across 42d Street and through the New York Central property to 43d Street and Lexington Avenue, all four tracks are parallel and at the same level. Here is the site of the new Grand Central Subway Station, containing two island platforms with mezzanines and the necessary entrance and exits. This is destined to become a great transfer point, facilities being provided for exchanges between the Lexington Avenue subway, the shuttle service to Times Square,

and the Queensborough Tunnel to the borough of Queens. Facilities will also be provided for entrances to the Grand Central Station of the New York Central Railroad Company, to the new Hotel Commodore, and to the new building to be erected on the site of the former Grand Union Hotel.

Across the Grand Union property the structure is designed to carry a 25-story building, and it is intended to sell the property, which was acquired in fee by the City, subject to a permanent easement for the maintenance and operation of the subway through it. Because of the heavy column loads to be carried, great care was taken to secure proper foundations. Sometimes the contractor's representatives thought the engineers were rather too particular and made them go to an unnecessary depth for the purpose, and some good-natured bantering took place about it. The work was well and faithfully done, and there was excellent coöperation between the engineers and the contractor to secure good results.

For the structure crossing the New York Central property between 42d and 43d streets, an easement was obtained from the railroad company, under the terms of which the company constructed the subway there, and the right was given the City to maintain and operate it. The new Hotel Commodore is now being erected over and about this subway structure, and, as before stated, there will be connections between the station platforms and this hotel, as well as with the Grand Central Station of the New York Central Railroad.

The pair of single-track tunnels now named the "Queensborough Tunnel," formerly known as the "Belmont," and earlier as the "Steinway Tunnel," extended east from Park Avenue under 42d Street and the East River to Long Island City in the borough of Queens. The tunnels, which were built between 1905 and 1907, have in part been reconstructed in connection with the Dual System program. The island platform east of Lexington Avenue has been extended over five hundred feet west, ending at a shaft about 63 ft. square east of Park Avenue, in which three passenger elevators operate between this station platform about 70 ft. below the street surface, and the mezzanine about 19 ft. below the street surface. The ex-

tension of the platform involved the lowering of the two existing tunnels a maximum of about 7 ft. and the removal of the core of rock between them for a length of about 535 ft., all of which extremely difficult work was accomplished without trouble, due to the ingenious methods and the care employed. This work was done before operation on that part of the Queensborough Tunnel was begun. Other features of this tunnel reconstruction were the excavation of the core of rock between the two tunnels for a length of about 240 ft. near the Manhattan shore of the East River, to provide for a crossover between the tracks; the extension of the two tunnels west to Vanderbilt Avenue from which point it is planned to extend them later with a view to carrying the operation to Times Square; and the construction of a tunnel ramp connection between the station of the tunnel and the new Grand Central subway station overhead. The difference in elevation between the two platforms is about 40 ft.

As the present routing of subway trains under 42d Street will be discontinued when the new Lexington Avenue and Seventh Avenue lines are placed in operation, provision is made for a shuttle service between the Grand Central and Times Square stations. In connection with this, two of the four tracks of the existing subway are to be extended east from the present Grand Central station to a point convenient for transfer to and from Lexington Avenue trains and Queensborough Tunnel trains. An extended platform is required by this change and is being constructed.

There is not time to describe the many interesting engineering features of the work in this vicinity. They are, however, covered in an excellent paper read to the American Society of Civil Engineers in December, 1917, by Mr. George Perrine, assistant tunnel engineer for the contractor, the Rapid Transit Subway Construction Company, of which Mr. George H. Pegram is the chief engineer. The tunnel engineer in charge for the contractor, Mr. Robert A. Shailer, is well known to the members of this Society, and the general superintendent, Thomas McCormack, deserves more than a word of commendation for the excellent manner in which this difficult work was carried out under his supervision. A false step or a little laxity might

easily have led to an appalling catastrophe. The cost of the work covered by the two contracts of the company in this vicinity will be about $3 500 000. There is still an opportunity for members of the Society to inspect this work, and the speaker feels that those who do so will feel amply repaid for the effort.

The connection between the present subway and the new Seventh Avenue line at Times Square, completed about two years ago under a contract with the Holbrook, Cabot & Rollins Corporation, also presented many interesting and novel features including the reconstruction of a part of the old subway under operation conditions. Here the depth of cover was so slight that in order to carry on the work of reconstructing the subway roof with a minimum of interference with the extremely heavy street traffic at that point, the decking for the temporary street surface between 43d and 45th streets was raised about 2 ft. above the street grade, the surface car tracks with their heavy underground construction being jacked up correspondingly. Ramps at each end of the stretch and at the intermediate street intersections connected the elevated decking or bridge to the existing pavements. Under the decking the work of cutting out the old roof and side walls and constructing the new was carried on. At the conclusion of the work the permanent street surface was restored approximately at the old grade. When it is considered that the clearance between the cars and the subway roof which was cut out and replaced was a matter of only a few inches, some idea of the difficulties of reconstruction will be appreciated.

The layout of the various new lines required the crossing of existing subways and other railways, exclusive of surface-car lines, at 15 points, 12 immediately underneath and 3 overhead, in addition to connections made to existing subways at grade. In every case but one the existing lines affected were in operation at the time the work was done. In the case of the overhead crossing of the Interborough Rapid Transit subway at Mott Avenue and 149th Street, it was necessary to put out a length of concrete arch lined with brick, which spanned two tracks and two station platforms, substituting a flat girder roof which formed the floor of the new construction overhead. Some

of the undercrossings were entirely in rock, the latter being in contact with the floor of the old construction. Some were partly in rock and partly in earth. One under the New York and Harlam tracks at Park Avenue and 60th Street was in an old rock fill with the soft ground of an old swamp below. Others were entirely in soft ground, ranging from coarse dry sand to saturated fine sand approaching quicksand. In several instances provision for the later subways had been made in the design of the earlier ones so as to make the task of maintenance while drifting under them easier, but generally this was not the case because when the earlier work was done the later subway routes had not been established. Each one of these crossings possessed features of peculiar interest to the constructing engineer, but reference will be made here only to the building of the two-track Canal Street subway under the four-track subways of the Interborough Rapid Transit Company and the New York Municipal Railway Corporation at Lafayette Street and at Cénter Street, respectively.

The Canal Street subway connects the Fourth Avenue subway in Brooklyn with the new Broadway Line in Manhattan, crossing over the East River on the Manhattan Bridge. The crossings referred to are between the bridge and Broadway. The surface of Canal Street at these crossings is about 13 ft. above m.h.w., and the subgrade of the lower or crosstown line is from 33 ft. to 35 ft. below m.h.w. in water-bearing sand of varying degrees of fineness, some of it being coarse and well graded enough to be used in the concrete. The rock lies at a considerable depth below subgrade. While no accurate figures are available, the contractor estimates that at the time of maximum pumping he took care of a flow of 10 mil. gals. daily, the water coming from various depths in a length of several hundred feet. The design of the Center Street Subway, built about ten years ago, provided a girder floor supported on concrete steel piles as a provision for the future work below it. The Lafayette Street subway made no such provision. When it was built between 1900 and 1904 the crosstown line had not been adopted; consequently it was more difficult to pick up and maintain. It was necessary to lower the ground water very carefully and gradually

in order to prevent a serious loss of material, but this was successfully accomplished. The pumping affected the water level for a large area, and complaints were received from buildings a half mile or so away which maintained pumping plants that the ground water at their pumps had been lowered enough to seriously inconvenience them, these buildings being nearer to the North River in some cases than to the work described. The water was fresh, notwithstanding the fact that pumping was maintained during the construction of this and the adjacent sections to the west for at least four years within three quarters of a mile of both rivers. The contractor, the Underpinning and Foundation Company, devised and successfully used an ingenious method of supporting the sides of the cut by means of concrete walls four feet thick instead of by the use of wood or metal sheeting. These walls acted likewise as lateral supports for the adjacent buildings. Not being gravity walls, however, it was necessary to securely brace them with an interior system of timber sets. The steel roof girders of the subway were in some instances used in connection with this system of bracing, being set 6 in. or more above their proper grade when the excavation had reached that depth and securely wedged against the faces of the protection walls. Afterwards, when the excavation was completed, these girders were loosened and lowered one at a time on their columns and riveted in place, the side thrust then being taken by the permanent steel and concrete structure. Careful consideration was given to the design of this subway before a decision was reached, and on account of the fact that it would be submerged in saturated sand, an opportunity was given contractors to submit alternative bids on a tunnel design that would permit the use of compressed air. The bids received indicated the adopted open-cut design to be a far more economical one than the tunnel design. On account of its great depth in water-bearing sand, this structure, which is completed and in operation, attracts more than usual interest, particularly the problem of waterproofing it. It is waterproofed generally by the use of brick in mastic. In special cases where there are concentrated loads, lead sheets are employed. It was required to connect this waterproofing to that of the existing structures,

and it is not necessary to point out to those who have had experience in such work the difficulty, if not impossibility, of securing an absolutely perfect job. Some annoying leaks developed, particularly during the extremely cold weather of the past winter, where the new and old structures are in contact, due, in measure at least, to the contraction of the masonry and the waterproofing. From the nature of things, these leaks are

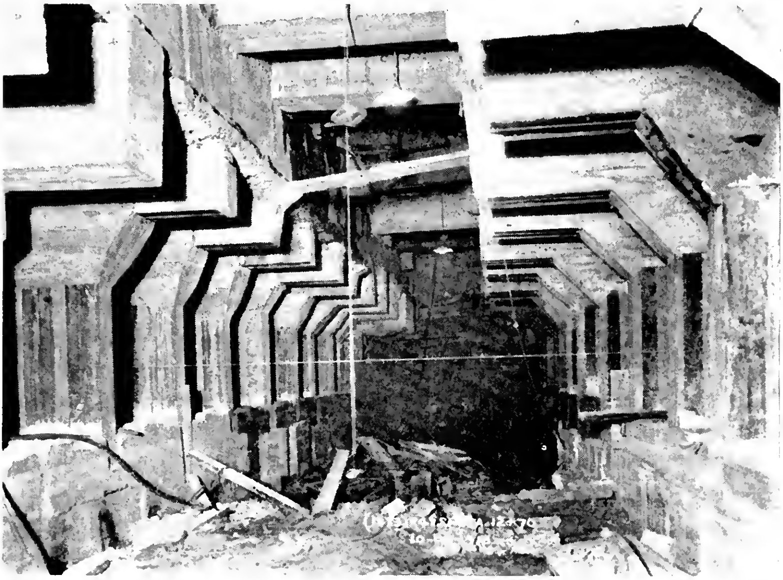

FIG. 9. PARK PLACE — BEEKMAN STREET SUBWAY AT THE LOCATION OF THE UNITED STATES POST OFFICE BUILDING.

very difficult to repair, but measures are being taken to correct them that will be effective, it is believed.

The Seventh Avenue Interborough Rapid Transit line is a four-track structure from a connection with the present tracks at Times Square down Seventh Avenue, Varick Street and West Broadway to Park Place, two tracks continuing down Greenwich Street and under Battery Park to a connection with the present South Ferry Loop. The other two tracks turn east under Park Place at a depth great enough to avoid grade cross-

ings at the turn-out, continuing under the two-level subway in Broadway, which forces the subgrade of this line to a depth of more than 60 ft. below the street. The structure then passes under the General Post Office Building (Fig. 9) at its widest part, under the Interborough Rapid Transit subway at Park Row, under Beekman Street in a soft-ground tunnel, down William Street in cut and cover, and under the East River to a connection with the present subway under Fulton Street near the Borough Hall Station. The alignment under the Post Office Building is so arranged that the center line of the structure coincides approximately with one of the lines of building columns, while the two adjacent lines of building columns follow approximately the side lines of the structure. The concrete foundations of the Post Office Building rested on sand, relatively coarse, approximately at elevation 103 ft. (elevation 100 ft. being mean high water), while the roof of the subway is from 6 ft. to 8 ft. below these foundations. The deepest point of the subway excavation is about 25 ft. below mean high water and about 28 ft. below the Post Office Building foundations. The ground-water level when work began was approximately 11 ft. below mean high water, and was slowly and carefully pumped down to subgrade as the excavation progressed, the pumping operations requiring months of time. Drainage ditches were used leading to temporary sumps from which the water was pumped into the sewers. The sequence of the contractor's operations were so arranged that the time so consumed did not delay the completion of the work. In all, 63 column and pier loads had to be carried to greater depths in connection with the subway construction, and are now supported either on the subway structure or on piers carried down to or below subgrade just outside of the walls. The heaviest pier or column load to be taken care of in connection with the underpinning operations was about 1 100 tons. The contractor, F. L. Cranford, Inc., and his engineer, James C. Meem, applied a very ingenious method for underpinning the building. Enough of the sub-basement floor was taken up to uncover the column foundations affected, and a portion of the longitudinal footing was cut off on each side of each of the three lines of columns. Thirty-inch built-up lattice girders

were placed against the column footings into which horizontal holes were drilled and $1\frac{1}{4}$-in. square dowel pins inserted between the diagonals of the lattice girders. On top of these 30-in. girders 15 ins. built-up lattice girders were placed transversely against the column footings and were enclosed in a mass of concrete, thus forming a reinforced concrete girder paralleling the subway structure for the full width of the Post Office Building, about 280 ft. Pits, 5 ft. by 5 ft. in horizontal section, were sunk at intervals under these girders to the level of ground water, and 14-in. sheet steel piles were driven or jacked down to a firm bearing below subgrade and filled with concrete, each pile being tested by hydraulic jacks, which reacted against the girder to a load 50 per cent. in excess of the calculated load it would have to carry. This meant that many of the piles were tested up to a load of 50 tons. When the necessary number of piles had been placed, the pit over them was filled with concrete, and its share of the load of the reinforced concrete girder and the building then was transferred to it. When the design required it, instead of filling the pit with concrete, a set of underpinning columns, so spaced as to permit the subway roof steel to pass between them, was erected in the pit on the pile cap. This method was continued until the entire length of each girder was supported by the concrete piers with their pile foundations, thus transferring the loads of the three lines of building columns and piers to the new underpinning structure. Then, the water level having been lowered in the meantime, the excavation was taken out to subgrade, exposing the steel piles as the work advanced, the subway construction followed up close and the column loads were again transferred, this time to the subway structure except those which had been permanently supported on underpinning piers outside of the structure. Such of the piles as were in the trackways were cut out, and the others were incorporated in the center or side walls of the subway. The slight settlement in the building overhead is not apparent from an inspection of the fine cut exterior granite faces, although cracks of no importance structurally appeared in the interior walls and in the plastering. The work described did not interfere in any way with the use of the building except that part of the sub-basement which

was occupied by the contractor in connection with his construction operations. The plungers for the elevator system of the building were located about 20 ft. away from the side of the subway excavation and were continuously operated without any trouble so far as is known to the speaker.

This same two-track subway passes under William Street for a distance of one-half mile. The width of the excavation is about 29 ft., increasing at the two stations to the full width of the street, 40 ft. The high office buildings give this narrow street a canyon-like appearance. The work was done by the cut-and-cover method, traffic being maintained on the temporary decked surface of the street, which decking was supported by the trench timbering. Spoil was removed through three shafts or hoistways, located at Hanover Square, at Maiden Lane, and on property acquired by the City where the line turns from Beekman Street into William Street. The depth of the excavation ranged from 25 ft. to 31 ft., extending from 3 ft. to 20 ft. below mean high water, the low point being at the south end of the section at the junction with the Old Slip-Clark Street river tubes. The water was slowly lowered by careful and judicious pumping as the work progressed. The material ranged from coarse to fine sand, with some clay. But for the care and foresight of the engineer and the contractor, great trouble would have been experienced in executing this work. The impression had been given some of the owners that it was not a practicable proposition to build a subway in this street without seriously damaging the buildings, but they have been reassured by the results. Every one of the seventy-five or so buildings facing William Street in this stretch required underpinning except a few of the more modern buildings which were supported on caissons extending to rock. The buildings ranged in height from four to twenty stories above the sidewalk, the highest one being the Kuhn, Loeb Building, at the southeast corner of Pine and William streets. This twenty-story building was also the highest one of the many hundred buildings underpinned in connection with subway construction. Its foundations, consisting of a grillage of steel beams enclosed in masonry floated on saturated sand, were approximately 15 ft. below the street level, and it was

necessary to carry them 15 ft. or so deeper and to cut off 5 ft. or more of the old grillages where they extended into the street occupying space required for the subway. Many novel and ingenious methods were used by the contractor in connection with the underpinning, and their success reflects much credit on this firm and its engineers. The contractor is Smith, Hauser & MacIsaac, Inc. It will cost, exclusive of track, about $2 500 000, of which approximately $600 000 represents the cost to the City of the underpinning.

The Dual System required the construction of four pairs of tunnels under the East River, excluding the Interborough tunnel now in operation from South Ferry to Joralemon Street, and the Queensborough Tunnel at 42d Street, before mentioned. With the Pennsylvania and Long Island Railroad tunnels, this will make eight pairs or sixteen single tubes available for transportation purposes under this river. The new tubes being constructed are the Interborough tunnel, from Old Slip, Manhattan, to Clark Street, Brooklyn, and the three New York Municipal Railway Corporation tunnels from Whitehall Street, Manhattan, to Montague Street, Brooklyn; from 14th Street, Manhattan, to North Seventh Street, Brooklyn; and from 60th Street, Manhattan, to North Jane Street, Queens. All of these four tunnels are of the usual type of circular, cast-iron lined tubes, shield driven under compressed air in the soft ground and in the rock where the latter structure was weak enough to require it. Where there was sufficient cover of good, sound rock, ordinary tunneling methods in free air were employed. The grades were fixed by the local conditions, and by the conditions of the War Department permits which required a minimum depth to the tops of the tubes at pierhead lines of 45 ft. below mean low water, or approximately 50 ft. below mean high water. The deepest one of these tunnels, in fact the deepest of all the transportation tunnels under New York waters, is the so-called 60th Street Tunnel (Fig. 10), the profile of which presents a number of interesting features. Blackwell's Island at that point divides the East River into two channels, the easterly one being comparatively shallow, while the deepest point of the westerly one extends down to the spring line of the tunnel. The lowest point

of subgrade was fixed about 110 ft. below mean high water. Soon after the contract was let, the contractor placed a blanket of clay of a thickness calculated to provide a cover of approximately 40 ft. over the shields while they are being driven. On the completion of the tunnel, some of this blanket must be removed, as the War Department permit requires 55 ft. of water in the channel at mean low tide. This blanket is held in place

FIG. 10. TUNNELING UNDER THE EAST RIVER FOR THE 60TH STREET TUNNELS.

by two walls of rip-rap, or rock tunnel spoil, extending across the channel, parallel with and about 50 ft. outside of the tunnel construction. The width of this embankment from outside to outside of rip-rap is approximately 120 ft. The current runs very strong at this point, as one would infer from the great depth and narrow width of the channel. Blackwell's Island is a rock of reef or ridge, and there is also rock both on the Manhattan and Queens sides. Shafts were sunk in the rock on the Manhattan side and on Blackwell's Island of a width sufficient to permit the

turning of the four tunnel headings, two in each direction. The Manhattan shaft is about 100 ft. deep, the Blackwell's Island shaft about 130 ft. deep. After the tunnel headings were turned, the permanent concrete lining was placed in the shafts which are to be used as ventilation openings and emergency exits. The contractor, the Patrick McGovern Company, of Boston, attacked the work in a most energetic way, and has made excellent and consistent progress from the start. The plan adopted was to drive the rock tunnels each way under Blackwell's Island and riverward from the Manhattan shaft and from the portal on the Queens side as far as it was safe to go without compressed air; also to extend the rock tunnels in free air landward under 60th Street, Manhattan. All of this work has been done and the tunnels are partly lined with concrete. For the subaqueous portion, two large shields were installed on the Queens side and to date have been driven under the east channel and into the Blackwell's Island workings. The south tunnel under Blackwell's Island was excavated large enough to permit the shields to be shoved through it while the north tunnel was excavated only to normal size and has l een lined with concrete. Beyond the limits of this concrete lining cross-connections were excavated between the two tunnels, to permit the rolling of the north shield through into the south tunnel, skidding it through the latter to the westerly cross connection and rolling it back again to the north tube to resume its journey under the west channel. These two shields, therefore, will be used for all of the subaqueous work, and it will not be necessary to install two additional ones on the Manhattan side. To date, the south shield having completed its work under the east channel has been skidded through the rock tunnel already excavated under Blackwell's Island and is now in a position to tackle the deep work under the west channel. It is expected in the course of a few weeks that the maximum air pressure of 45 lbs. or more will be on, and the engineers are looking forward with interest to this phase of the work. Those of the membership who attended the annual meeting of the American Society of Civil Engineers probably visited the Queens end of this tunnel by invitation of Mr. McGovern, and will remember the hospitality of the contractor, who entertained

the party at a luncheon served in a section of the completed subway there. The shields being used were designed by the contractor and his engineer, Mr. A. A. Cohill, in coöperation with Mr. J. R. Worcester, of Boston, and embody some unusual features.

The speaker has attempted to sketch in a general way a few of the many interesting features of the subway construction with which he has been connected during the past six years, but it is not possible to describe them in detail at this time. There are many other features of the work quite as interesting as those which have been mentioned, such as the excavations in deep dry sand in Brooklyn, the passing under and underpinning of the Long Island Station at Flatbush Avenue, and the deep earth tunnel under a portion of Flatbush Avenue at Prospect Park, where the contractor is using a roof shield spanning two tracks, moving it ahead on concrete bench walls previously constructed in timbered drifts. Time could also be spent describing the changes in sewers made necessary on account of subway construction, these changes costing in the aggregate millions of dollars. A paper could also be written on the work of maintaining, restoring and reconstructing the intricate system of underground public utilities on which so much of the business and social life of the greater city depends.

The work described has been done by contractors supervised by the Engineering Department of the Public Service Commission for the First District of the State of New York. The contractors employed a maximum force of probably 18 000 men during the period of greatest activity. Their present force is about 7 000 men, though at least 50 per cent. greater force could be worked to advantage if it could be secured; but war conditions seem to make this impracticable. Prior to 1912, the contracts were let on the lump sum basis. Since then, with very few exceptions, the unit price method has been followed. This necessarily means dozens of schedule items in all of the major contracts, and the work involved in connection with the making of the monthly and final estimates is a severe tax on the field and office staff. It is difficult, however, to simplify this work if the unit form is to be followed. The speaker believes

that in spite of all these and other objections to it, the unit price form of contract is preferable to the lump sum contract for such work as that under discussion here. The maximum force of all grades employed by the Engineering Department of the Commission was 2 127 in December, 1915. This has been largely reduced since, the present force being 1 200 men of all grades. It is hardly necessary to state that the war, directly and indirectly, has drawn very heavily on the force and impaired the efficiency of the department. The commission's service flag has 255 stars, representing men in the military and naval service of our country, most of them from the Engineering Department. Many of these men are on duty in France. Four were officers in the Engineer Regiment which distinguished itself so conspicuously near Cambrai on November 30, last, and one of them was cited by the British commander with other members of the regiment for distinguished gallantry on that occasion.

The commission and its chief engineer, Mr. D. L. Turner, as well as the speaker, extend an invitation to the members of the Society, collectively and individually, to visit the work which is being done in connection with the Rapid Transit System of New York, and it would give the speaker pleasure to arrange for such visits at such times as may be convenient to the members.

MEMOIR OF DECEASED MEMBER.

CHARLES W. GAY.*

(Died February 1, 1918.)

Charles W. Gay was born in South Dedham, now Norwood, Mass., April 28, 1848, the son of Ebenezer F. and Sarah A. (Webster) Gay.

After completing courses in the Dedham public schools he entered the office of the late Prof. John B. Henck, of the Massachusetts Institute of Technology, and was engaged on laying out large portions of the Back Bay district of Boston, which work was considered at that time to be one of the most accurate surveys that had been made in Boston, and later continued his studies in the office of Col. H. W. Wilson, Boston, where he was engaged in preparing assessors' maps of South Boston.

About this time he was engaged on important street planning in Washington, D. C., laying out new lines under the direction of the national board of public works.

In 1872 he opened an engineering office in Lynn, Mass., where he continued to work at his profession until his death. He prepared plans for and supervised the work of construction of Birch Pond for the Lynn Water Works during 1873-75.

He entered public life in 1884 as a member of the common council, and in 1888 was elected city engineer of Lynn, which office he held eight years, later serving the city as a member of the board of public works seven years. He was of modest disposition but did not hesitate to assert himself in public print, and was ever alert to the possibilities of the future development of Lynn.

He was an expert surveyor, and was considered an authority

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* Memoir prepared by William L. Vennard and Frank B. Rowell.

on real estate boundaries in Lynn and vicinity; and few men had more to do with street and civic development in the vicinity of Lynn than Mr. Gay. He laid out a large part of Swampscott and Nahant, and in the eighties began the construction of the sewer system of Lynn.

He was of the sterling type of men, with high principles, and a true friend to those who won his friendship. He was married, January 27, 1873, to Rosamond A. McLaughlin, in Andover, who with his sister survive him.

Mr. Gay was a member of the American and Boston Societies of Civil Engineers, was a thirty-second degree Mason, a member of the Mystic Shrine and local clubs.

The loss of his daughter, Florence Webster Gay, in December, 1917, greatly affected him, and doubtless hastened his death, as he had been suffering from heart and kidney trouble.

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BOSTON SOCIETY OF CIVIL ENGINEERS
FOUNDED 1848

PAPERS AND DISCUSSIONS

THE SANITARY CONTROL OF SWIMMING POOLS.

By Stephen DeM. Gage,* Member of Boston Society of Civil Engineers.

(Presented before the Sanitary Section, December 5, 1917.)

Something over seven years ago, while the speaker was connected with the Massachusetts Board of Health, we were asked to advise the operators of two swimming pools as to what methods to employ to ensure a water which should be both clean and safe for bathing. Both pools were new and up to date, and were equipped with filters for repurifying the water. Although we had little practical knowledge of swimming pool operation as such, we had had a wide experience in the operation of the various methods of water purification at the Lawrence Experiment Station, and approached the problem with the feeling that a few weeks' experimental work to tune up the filters and get them working properly would probably solve all difficulties. We soon discovered that there are a number of factors involved in the sanitary operation of a swimming pool which do not have to be considered in problems connected with the purification of water for other purposes, and our experiments with these two pools were continued for nearly a year before the operating methods had been adjusted to yield satisfactory results.†

As the fact that these studies were in progress became known to other swimming-pool operators, other requests for advice

* Chemist and Sanitary Engineer, Rhode Island State Board of Health.

† Clark and Gage, 1912 Report Massachusetts State Board of Health, pp. 346–367.

were received, and the investigation was extended to other pools. In each case we found different conditions, different equipment, and a different problem which required a somewhat different method of solution. It became evident then that until pools and equipment should be standardized, the sanitary control of each swimming pool would be an individual problem, and that even could we standardize pool and equipment we would still be unable to standardize the bathers.

During the past year we have been engaged in an investigation of the various swimming pools in Rhode Island, in which we have endeavored to obtain as complete information as possible as to all details of construction, equipment, methods of operation, etc., which might in any way affect those sanitary conditions. As my part of the program to-night I propose to discuss various aspects of the swimming-pool problem, using the Rhode Island pools as an illustration of conditions which are more or less general throughout the country. Throughout the investigation we have received the hearty coöperation of the swimming-pool operators, who realize that they have been working in the dark and welcome any criticism or suggestion which will enable them to improve conditions or make their pool more attractive. It should be clearly understood that conditions as we found them are reported for purposes of illustration, and in certain instances those conditions have been or will be greatly improved as the problems of the different pools are worked out and the best method of operation to suit individual conditions is determined.

Swimming Pools and Disease.

Each bather carries a certain amount of pollution into the pool no matter how thoroughly he may have attempted to wash himself before entering, and there is always a possibility that infectious material may thus be introduced and transmitted to other bathers. The list of diseases which may be transmitted by these means includes not only the usual water-borne diseases, — typhoid, dysentery and other infections of the alimentary canal, — but also a number of diseases which do not

have to be considered in ordinary water-supply problems. In a number of instances, epidemics of colds, sore throat, and similar infections have been reported among users of swimming pools, and in one instance a number of cases of pneumonia occurred among the members of a swimming team. Infections of the ears and of the eyes in certain cases have also been attributed to use of swimming pools.* There also appears to be a general fear in some quarters that skin diseases and venereal diseases may be transmitted through this means, and during the past summer the pool at the Army and Navy Y. M. C. A. at Newport was closed on account of a feeling that it might become a medium for infection of this nature. The number of authentic cases of infection through swimming pools is extremely small, when the large number of persons using such pools throughout the country is taken into account, and from all evidence at hand the danger of transmission of disease through this medium must be considered relatively slight.

Nevertheless it should be clearly recognized that such danger may exist, and that the sanitary control of swimming pools is essentially a public-health problem which should come under the jurisdiction of the public health authorities. In California and some other western states, all bathing establishments, swimming pools, etc., are already under state supervision. The methods for properly controlling the purity of the water in a swimming pool require expert chemical and bacterial knowledge which the usual swimming-pool operators cannot be expected to have, and the placing of such knowledge at their disposal through state supervision would in many instances lead to improvements in operation by which the possibility that the pool might become a medium for infection would be reduced to a minimum.

Bathing Load.

The relative proportion between the number of bathers using a swimming pool and the capacity or volume of that pool

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* All references to recorded cases of infection from swimming pools are omitted here, as a complete bibliography of the subject will be found elsewhere in this Journal. An unreported epidemic of conjunctivitis occurred among users of a swimming pool in a neighboring state about five years ago.

has an important bearing upon the sanitary condition of the water. To state the question baldly, a swimming pool may be likened to a big tub in which a considerable number of persons take a bath in the same water. Obviously, if the pool is small and the number of bathers large, the contamination of the water will be much greater than if the reverse is true. In certain instances this relationship has been expressed by assuming the water to be equally divided among the persons using the pool in a given time. This method of expression permits a comparison between the probability of contamination of different pools, but as the results are in inverse ratio direct comparison is somewhat difficult.

For purposes of comparison, I have used a somwehat different method of expression, which for lack of a better term I have called the " Bathing Load." This expression, which gives values in direct proportion to the probability of pollution, is obtained by dividing the number of bathers using the pool by the volume of water in thousand gallons. As the attendance usually varies considerably on different days of the week, and as pool usage, cleaning, disinfection, etc., are usually run in weekly cycles, the weekly bathing load is probably the most convenient term for general purposes, although daily, monthly or yearly bathing load figures may be useful in special cases. Experience elsewhere has shown that the amount of pollution introduced into the water is influenced to a certain extent by the age, sex and degree of personal cleanliness, of the persons using the pool. With equal requirements as to preliminary bathing, women will contaminate a pool more than men and children more than adults. From any available data, however, it is impossible to determine just what corrections should be applied to the computed bathing load for different classes of bathers, and for general purposes the uncorrected figures are sufficient.

The fourteen indoor pools in Rhode Island vary in capacity from 9 500 gals. to 75 000 gals. Three of these pools have capacities of over 50 000 gals., and six others have capacities of 30 000 gals. or over. The normal attendance at these pools varies from about 90 per week to about 1 200 per week, and the

normal weekly bathing load varies from 2.0 to 24.0. The capacity, average attendance and normal weekly bathing load for each of the Rhode Island pools are shown in Table 1.

TABLE 1.

CAPACITY, BATHING LOAD, ETC., OF RHODE ISLAND SWIMMING POOLS.

	Dimensions, Feet.				Capacity, Gallons.	Bathers per Week.	Weekly Bathing Load.	Average Days Operated without Refilling.
	Length.	Width.	Depth. Max.	Depth. Min.				
Brown University*	75	25.0	7.50	4.5	75 000	450	6.0	120
Pawtucket Boys' Club	70	25.0	6.25	3.5	65 000	130	2.0	5
Providence Y. M. C. A.*	60	21.5	10.67	3.0	50 000	1 200	24.0	105
Newport Y. M. C. A.*	40	30.0	6.00	4.5	45 000	600	13.3	110
Pawtucket Y. W. C. A.*	42	16.0	7.00	3.5	30 000	87	2.9	310
Woonsocket Y. M. C. A.*	40	20.0	7.00	3.0	30 000	240	8.0	160
U. S. Naval Training Station (3 pools)	40	20.0	7.00	5.0	30 000	135	4.5	1
Pawtucket Y. M. C. A.*	35	21.0	6.50	3.5	28 000	600	21.4	45
Newport Army and Navy Y. M. C. A.*	45	20.0	6.00	2.5	28 000	300	10.7	65
Moses Brown School*	38	14.0	6.00	4.0	21 000	325	15.5	80
Aborn Street Baths	25	18.0	5.67	4.9	18 000	88	4.9	14–21
Lundin Baths	20	16.0	4.00	3.9	9 500	75	7.9	3–7
State Sanatorium†	170	45.0	4.50	1.5		580		1

When the bathing load is large, more care and attention is necessarily required to keep the pool clean and the water in a sanitary condition than where the load is small. At the Pawtucket Boys' Club, where the pool receives no attention between the weekly refillings, the fact that the water does not become badly contaminated may be attributed to the very low bathing load. At times, of course, the number of bathers using a pool will greatly exceed the normal, and at such times a variation in the cleaning or purification practice may be necessary to properly care for the extra load.

After the declaration of war, in 1917, the various Y. M. C. A. pools were thrown open to enlisted men, and there was a large

* Pools operated by continuous repurification method.

† Outdoor pool with continuous flow.

increase in the daily attendance. A most interesting but rather disastrous incident resulted from this free bathing privilege while the Rhode Island troops were being mobilized in August. During the extreme hot weather which marked the week of August 4, the men were marched in continuous relays to the Providence Y. M. C. A. for a bath and swim. The records show that during this week more than 12 000 bathers entered the pool, and the bathing load jumped to over 240, or more than ten times the normal load. While it had been possible to keep this pool in a cleanly condition with a greatly increased number of bathers throughout the early summer, the purification system was entirely inadequate to handle this enormous load, and it became necessary to close the pool for cleaning and refilling at a time when it was extremely desirable that it should be open for continuous use.

Design and Construction.

Swimming pools should be so designed that there is shallow water at one end, for timid bathers or beginners, and water of sufficient depth at the other end for a person to dive without danger of striking the bottom. The size or capacity of a pool should be planned with some reference to the number of bathers which it is expected to serve. If the pool is to be operated on the continuous repurification plan, the inlets and outlets should be so located that there will be a proper circulation through the pool at times when the water receives no mixing from the movements of bathers. Even if the pool is designed to be operated on the fill-and-draw principle, unless a practically inexhaustible supply of water is available at low cost, it should be so arranged that a repurifying system can be installed later if it is found desirable to change the method of operation. The type of filters to be used should be carefully selected to ensure proper purification and ease of operation, and the filters, circulation pumps, and piping systems should be of sufficient capacity to provide for any emergency. The design and construction of a swimming pool, therefore, is essentially an engineering problem for the solution of which a thorough knowledge of hydraulic and sanitary engineering is required.

The variation in shape and arrangement of some of the Rhode Island pools is shown in Figs. 1 to 9 inclusive. In these sketches the vertical scale is double the horizontal scale, and the

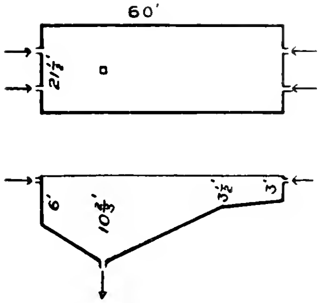

FIG. 1.

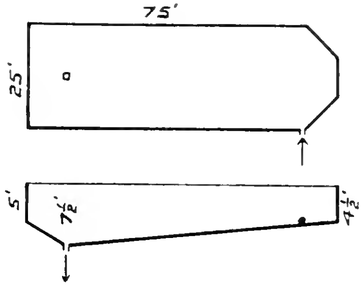

FIG. 2.

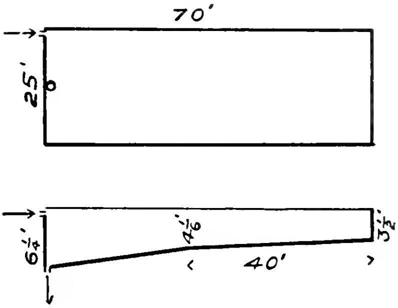

FIG. 3.

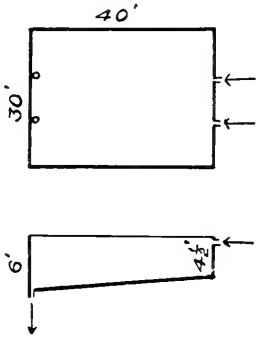

FIG. 4.

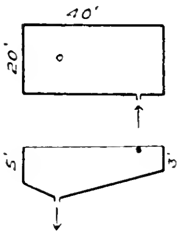

FIG. 5.

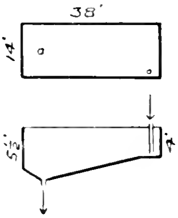

FIG. 6.

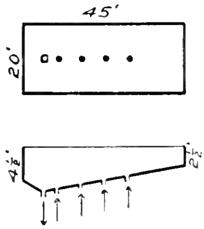

FIG. 7.

SOME RHODE ISLAND SWIMMING POOLS.

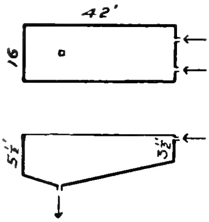

Fig. 8.

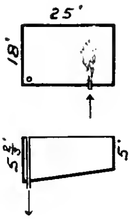

Fig. 9.

Rhode Island Swimming Pools.

slope of the bottom of the various pools is thereby considerably accentuated. The location of the inlets and outlets are shown by the arrows, which fly with the current. While in many cases pools have been constructed with the bottom sloping from one end to the other, as in Fig. 4, the usual practice is to slope the bottom from both ends to an outlet located about ten feet from one end, and frequently to provide a considerable area of shallow water with comparatively flat bottom. The object of such design is, of course, to provide both deep and shallow water and at the same time to cut down the construction cost and reduce the volume of water required for filling. The Pawtucket Boys' Club pool (Fig. 3) was designed primarily for the use of young boys, and it will be noted that shallow water is provided for about half the length. A somewhat smaller shallow area, with slight slope, is also to be observed at one end of the pools at the Providence Y. M. C. A. (Fig. 1) and the Moses Brown School (Fig. 6). The plan of the large pool at Brown University (Fig. 2) has been criticized somewhat severely by the swimming instructor, as, while the semi-octagonal shaped end is very effective architecturally, it materially reduces the number of bathers who can be started at one time in a swimming match.

In only two of these pools (Figs. 1 and 4) are inlets and outlets so located that a reasonably good circulation of the water can be obtained. At the former pool the outlet is located at some distance from the deep end, but there are two inlets at each end of the pool which can be throttled if necessary to maintain a proportional distribution of the entering water. Theoretically, the arrangement of inlets and outlets shown in Fig. 4, with two inlets equally spaced at the surface of the shallow end

and two outlets similarly spaced close to the wall at the deep end, should give a more uniform circulation of the water through the pool than any of the other designs illustrated.

The pool at the Pawtucket Boys' Club (Fig. 3) was designed to be operated on the fill-and-draw principle. As long as this pool continues to be operated in this manner, the location of inlets and outlets is immaterial. As this pool is already equipped with filters it could be changed into a continuously operated pool at small expense, but with the present arrangement of inlet and outlet a proper circulation of the water could never be obtained. With inlets and outlets located as in Fig. 8, although there is probably a good circulation throughout the greater part of the pool there is probably a considerable volume of dead water at one end when the pool is not in use. With the designs shown in Figs. 2, 5 and 6, there must necessarily be a short circuit from inlet to outlet with very little mixing of the water in the greater part of the pool other than that caused by bathers.

A peculiar arrangement of inlets and outlets is to be noted in the pool at the Newport Army and Navy Y. M. C. A. (Fig. 7). The jet effect of the water entering through the four inlets in the bottom of the pool undoubtedly causes some mixing at those points, but it is very doubtful if this mixing is as thorough as the designer intended to produce, and there is probably much dead water in the pool. A rather interesting attempt to maintain a semblance of circulation in a poorly designed pool was found at the small pool at the Aborn Street Baths. This pool has a combined inlet and outlet in one corner, with an overflow pipe near the outlet by which a constant water level is maintained. From a water jet on one side a spray is thrown over a portion of the surface. The amount of circulation obtained by this device is probably not very great, but the spray is said to be very popular with the bathers.

There should be a broad walk extending entirely around the pool, with a slight pitch to a drain connecting directly with the sewer, in order that dirt, etc., may not be washed into the pool. This is the construction at all except two of the Rhode Island pools. At the Moses Brown School there is an elevated walk above one side of the pool with no drainage, and the other walks

drain into the scum gutters. At the Providence Y. M. C. A., the walks pitch toward a shallow gutter near the edge of the pool, which drains through outlets directly into the recessed trough beneath. The walks around the pool, and especially the rounded edge of the pool, should always be corrugated or of rough material to prevent danger from slipping. At most of the Rhode Island pools, the edges are of smooth tile, but in a few cases rubber mats extending close to the edge are provided.

All pools, unless very small, should have steps or ladders at both ends, preferably at opposite corners. These should be constructed with rounded corners and edges and should have roughened treads to lessen the danger of accidents. It is much better practice also to have these steps or ladders recessed into the wall, thus leaving the pool entirely free from obstructions, and this is particularly desirable if the pool is to be used for water polo and other aquatic sports.

The finish or lining of the pool has an important bearing on the sanitary control. A smooth continuous surface, with rounded corners and no cracks, is most easily kept clean and therefore most desirable. Tile or enameled brick makes an excellent lining if properly set with well-filled joints. It is important that this lining should be white, or light colored, in order that the condition of the water and of the sides and bottom of the pool may be readily noted. In fact, a white lining against which any dirt is conspicuous is one of the greater incentives for the maintenance of cleanly conditions. All but one of the indoor pools in Rhode Island are furnished with a white tile lining which fulfills these requirements.

The floors and walls of the adjoining bath-rooms, toilets and dressing rooms, and also all lockers and furniture, should be vermin proof and should be constructed of impervious material to permit frequent washing and disinfection. A separate enclosure with separate entrances should also be provided for spectators.

Spit Troughs.

Spit troughs, overflow troughs, scum gutters, or wash troughs, as they are variously called, are usually built into the

wall of a swimming pool on one or more sides. These troughs are intended to serve a double purpose, that of a convenient handhold for the tired or exhausted bather, and that of a receptacle into which the bather may spit, and for the slop from the pool. These troughs should always be connected directly with the sewer, and should be so designed and constructed that sputum and other matters deposited in them cannot be washed back into the pool. The water in the pool should always be maintained at such a level that there will be enough slop during bathing hours to flush the trough. In the best designs these troughs are recessed instead of projecting from the side walls in order that danger of bathers being injured by striking them in diving or during water sports may be avoided.

Five of the Rhode Island pools have spit troughs on all four sides, and four others have them on three sides. In only two pools has no provision been made for spitting. In all but three cases, however, the design of the spit troughs are faulty in that they either project beyond the side walls or are so constructed that matters deposited in them may be washed back into the pool. At two of these pools the water is maintained considerably below the proper level, in order to cut down the waste of water. This effectually prevents matters from poorly designed troughs being washed back into the pool, but it also reduces the wash water below that needed to carry those matters forward to the sewer connection.

The designs of some spit troughs are shown diagramatically in Figs. 10 to 15, inclusive. Fig. 10 represents what is probably

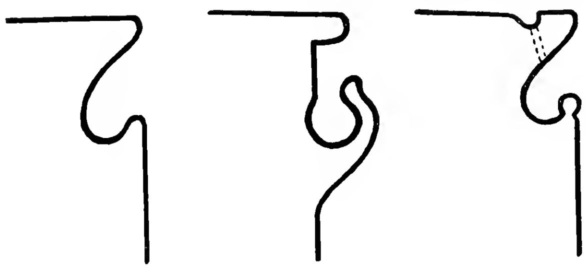

Fig. 10. Fig. 11. Fig. 12.

Types of Spit Troughs.


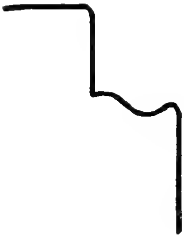
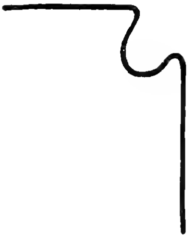

Fig. 13. Fig. 14. Fig. 15.

Types of Spit Troughs.

the earliest attempt to provide a place for spitting. In some instances these consisted merely of cups placed on the side walls, although generally they were built as troughs along one or more sides of the pool. As these cups or troughs projected beyond the side walls, there was more or less danger that bathers might be injured by striking against them. Figs. 11 and 12 show attempts to eliminate this fault by cutting the troughs back into the side walls. With either of these designs there was still some danger that a bather might slip on the edge of the pool and strike the edge of the trough in falling. With a design like that in Fig. 11, bathers are also likely to step down into the trough and thus disseminate sputum, etc. The type shown in Fig. 12 is less objectionable from both these viewpoints, but the water level must be kept so near the top of the pool that considerable water will be slopped out upon the side walks.

Fig. 13 shows an attempt to overcome these defects by constructing a trough which is entirely recessed in the wall. This type of trough is found on some of the pools built eight or ten years ago, and is excellent except in the one particular that the contents may at times be washed back into the pool. Figs. 14 and 15 illustrate designs intended to do away with these various objectionable features. Of the two, the writer considers Fig. 14 to better fulfill all requirements, although Fig. 15 is a popular design and has been used on a number of recently constructed pools. With either of these patterns it is still possible that the trough may be flooded by an extra large wave and apparently this fault can only be overcome by making the troughs of considerable size.

Heating, Lighting and Ventilation.

Adequate lighting must be provided so that every part of the pool may be visible at all times. For night use, indirect lighting is best, as shadows in the pool and its surroundings are avoided and the danger of accidents is reduced. It is desirable also that the pool be so located that it will receive direct sunlight during a part of the day, either from windows or skylights. Good ventilation of the room which contains the pool and of the bath and dressing rooms is essential. Even with the best ventilation it is difficult at times to prevent walls and furnishings in the vicinity of an indoor swimming pool from becoming musty, owing to the excessive humidity. Whenever mechanical ventilation is used, the incoming air should be heated, and the air ports should be so arranged that direct drafts will not strike the bathers. Either direct or indirect heating may be used, but provision should always be made for extra heat for the rooms containing the pool and the baths. Some means must also be provided for heating the water in the pool.

For comfort and to ensure the best hygienic conditions, the temperature of the pool should be about 70 to 72 degrees Fahr., and the temperature of the air should be about 75 to 80 degrees Fahr. For the control of the bacterial content of the water it would be better if an even lower pool temperature could be maintained, as even a few degrees in temperature make a tremendous difference in the multiplication of bacteria in the water. In some places it is stated that the bathers complain and the attendance falls off unless considerably higher temperatures than those stated are maintained, and as many pools are run largely to draw membership and help pay running expenses this argument must be given due weight. Hygienically considered, these higher temperatures are enervating and detrimental to the health of the bathers. The dressing rooms should be located well away from the pool and bath-rooms, should not be heated above 70 to 72 degrees Fahr. in winter, and should be thoroughly ventilated. Many a winter cold has originated from a bather going out into the winter air after dressing in a room where the temperature and humidity were too high.

All of the indoor pools in Rhode Island are lighted during the day by windows or skylights, and in nearly all cases are dependent upon these for ventilation. Steam coils or radiators are quite generally relied upon for heating. At the Lundin Baths the pool is close to the Turkish or hot room, and the air temperature is about 100 degrees Fahr. At four of the other pools the temperature of the air is kept at 80 to 85 degrees Fahr., and at the others the air temperature is maintained at 70 to 75 degrees Fahr. At all of the pools which are operated on the repurification plan the water is heated by some form of heater placed on the circulation system. At the Pawtucket Boys' Club the water is heated by the injection of live steam while the pool is being refilled, and the temperature is maintained by steam radiators in the pool. Live steam injection is also used to heat the pool at the Aborn Street Baths. The pool at the Lundin Baths is not heated, and in winter is used only as a plunge. At two of the pools the water is maintained at 76 to 80 degrees Fahr., and at the others the temperatures range from 68 to 73 degrees Fahr.

Preventive Sanitation.

Under this head are included all those measures which apply to the bathers and to the surroundings of the pool, the object of which is to promote cleanliness, to prevent the pollution of the water, to protect the health of the bathers, and to guard against accidents. Individually these numerous little details may appear to be of minor significance, but collectively they play a very important role in swimming-pool sanitation.

All bathers should be required to take a preliminary bath in the nude with warm water and soap before entering the pool. Some persons assume that, because they have had a bath that morning or some other morning, another bath is an unnecessary function, and take the preliminary bathing requirement as a reflection on their personal habits. As the patrons of a swimming pool usually come from all walks of life, this rule is necessary for the protection of all, and no discrimination can be made without the rule gradually becoming a dead letter. At those pools where bathing suits are permitted, great care must be

taken to see that this bath is taken in the nude, as persons who feel that the proper procedure is to don the bathing suit before taking the shower are not nearly as rare as might be expected. The thorough cleansing of every part of the body and the subsequent removal of all soap and dirty water are of the utmost importance. The bath-rooms attached to most swimming pools are equipped only with overhead showers, the spray from which cannot be made to reach all parts of the body. The writer has repeatedly seen men and boys passing from the bath room to the pool with a distinctly visible lather under the arms and between the legs, and it is undoubtedly the case that much of the pollution carried into a swimming pool is due to the imperfect cleansing of these parts of the body. Upward sprays of the Bidet type should be provided in all bath-rooms in addition to the showers, and all bathers should be taught to use both properly. An attendant should always be present during bathing hours, to supervise the thoroughness of the preliminary baths and to exclude diseased or otherwise undesirable persons.

Whenever it is possible to enforce such a regulation, all persons should be required to bathe in the nude. At first there was much opposition to this rule when it was adopted at some of the older pools, but its great value as a sanitary measure has come to be clearly recognized at all pools for men and at a few of the pools used by women. No diseased person should under any circumstance whatever be permitted to use a swimming pool or common bathing facilities, and the great advantage of nude bathing is that it permits such persons to be recognized and excluded from the pool. Nude bathing also tends to promote a greater degree of cleanliness among the users of a pool and thus aids in preventing pollution. If bathing costumes are permitted, they should be of fast colored non-linting material and should be limited to a one-piece suit. These suits should be furnished by the management and even if owned by the patrons should be left at the bath-house and thoroughly sterilized each time used. Even when nude bathing is the rule, the use of tight fitting rubber caps should be encouraged. Much of the sediment which accumulates on the bottom of a swimming pool is composed of hair which could have been kept out of the water

by the use of bathing caps. In this particular also the use of a tight-fitting suit of close material might be an advantage rather than a disadvantage, although the sanitary value of nude bathing appears to far outweigh any advantage which would be obtained in this manner.

Spitting in the pool or anywhere else except in receptacles provided for the purpose should be absolutely prohibited. Every bather takes more or less water into the mouth in swimming, and unless the "no spit" regulation is rigidly enforced this water may contain fresh, and therefore potentially dangerous, mucus recently ejected by some other bather.

It is almost needless to say that no common drinking cups, towels, common brushes and combs, should be permitted anywhere in a bathing establishment. Individual soap and towels should be supplied by the management, and the latter should be washed and sterilized each time used.

Water-flushed toilets and urinals should be conveniently located to the pool and bath-room, and every bather should be instructed to completely empty the bladder before entering the water. Some persons have a constitutional weakness which compels them to involuntarily pass urine when bathing, and every precaution must therefore be taken to prevent contamination of the pool from such sources.

Except in the case of janitors or attendants, no person in street dress should be permitted on the walks around the pool or in the bath and toilet rooms used by bathers.

A bathing attendant or swimming instructor skilled in methods of rescue and resuscitation should always be present during class hours or when the pool is used by children. All apparatus necessary for rescue and resuscitation should be conveniently placed ready for instant use. The water in the pool should always be kept sufficiently clean to permit bathers to see the bottom before diving, and when the water is drawn off all doors should be locked or roped off to prevent any one from diving or falling into the empty pool.

There should be a limit to the time bathers are permitted to stay in the water or around the pool. It is not unusual, especially during swimming competitions, to see bathers standing

around the pool awaiting their turn, shivering and chattering their teeth. Swimming is undoubtedly a healthful exercise, but too long a stay in the water or in the warm, damp atmosphere surrounding the pool is debilitating and may lead to colds or more serious trouble. Thirty minutes in the pool is probably long enough for the average person, and this period should be reduced for persons not in the best of health.

The sanitary regulations and the means taken to enforce them vary widely at the different pools. At certain pools, as for example at the Providence Y. M. C. A., all bathers must pass through the shower-bath room to reach the pool. At nearly all the pools conspicuous notices are posted calling attention to the preliminary bathing requirement. In some instances talks on personal hygiene and cleanliness are given to the different gymnasium and swimming classes in which the necessity of the preliminary bath as a sanitary measure is emphasized.

At all the men's pools in Rhode Island nude bathing is the rule, and suits are permitted only during swimming competitions when visitors are present. At the Pawtucket Y. W. C. A. and at the Pawtucket Boys' Club and the Woonsocket Y. M. C. A. during the hours assigned to women, bathing suits are permitted. At both the Pawtucket Y. W. C. A. and the Pawtucket Boys' Club, the bathing costume for women is limited to a one-piece suit, and at the latter place clean suits are supplied by the management. At Woonsocket the pool is used once each week by women who bring their own suits. At the Pawtucket Y. W. C. A. and at most of the Y. M. C. A. pools, soap and clean towels are furnished by the management, usually for a small fee, and private soap and towels are prohibited. At many of the swimming pools a medical examination is required of bathers, but in the majority of cases this examination is made only when the person registers for the bathing or gymnasium classes, and only at the schools and colleges is any attempt made at regular medical supervision.

Measures for the prevention of accidents are more or less intimately connected with sanitary measures. Most of the Rhode Island pools have scum troughs on the sides, which serve as handholds for bathers, and at the pool at the Moses Brown

School, there is a handrail along one side just above the water. Shallow water should be provided at one end of the pool, for bathers who have not learned to swim. At all of the Rhode Island pools, attendants are present during certain assigned hours, but at most of these places bathers are also permitted to use the pool at other times. At all the pools, however, regulations prohibiting bathing alone are posted in conspicuous places. At the Army and Navy Y. M. C. A. pool at Newport, where there are no spit troughs or other handholds for bathers, the caution against bathing alone is printed in large letters on the wall above the pool. At some of the pools there are call bells conspicuously marked, which can be used to call assistance in case of accident.

Methods of Keeping the Water Clean.

Swimming pools may be classified as those which are refilled when the water becomes too dirty for use, and those at which filtration, dilution and disinfection are relied upon to keep the water clean and which are emptied and refilled only at long intervals. Undoubtedly the best and most cleanly method of operating a swimming pool is to empty it, thoroughly clean the sides and bottom, and refill it with fresh water every day. This is the practice with the three pools at the U. S. Naval Training Station at Newport, where an unlimited supply of salt water is available. In most cases the expense of this method of operation is prohibitive, and those pools which are operated on this principle are kept in operation for somewhat longer periods, usually until the water becomes noticeably dirty. At the Lundin Baths and Aborn Street Baths the pools are refilled at intervals of three to seven days, and of two to three weeks, respectively, depending on the number of persons who have used the pool. At the Pawtucket Boys' Club the pool is operated on a regular weekly cycle, being emptied on Sunday and cleaned and refilled on Monday. At this pool there is usually a considerable amount of sediment on the bottom by the end of the week, and at times the water has an appreciable stain and a noticeable scum on the surface.

Where the water must be taken from the city mains, the cost of the water for refilling and the cost of heating it in cold

weather make this method of operation an expensive one. For example, the cost of water for filling the Boys' Club pool is approximately four dollars, and about three tons of coal are required to heat this water to the desired temperature. With coal at present prices the operating expense on account of these two items is well over thirty dollars per week in the winter. At this pool the city water is so highly colored and so much iron is stirred up in the pipes during refilling that all the water is filtered before used. Although the pool could probably be emptied, cleaned and refilled between Saturday night and Monday morning, the extra time consumed in filtering the water reduces the actual time this pool can be used to about five days per week.

The open-air pool at the State Sanatorium for Tuberculosis is in a class by itself. This pool, or artificial pond with natural earth bottom, was constructed in an old mill race. By means of head gates the water can be let into the pool at any desired rate, and by raising or lowering flashboards on the dam at the outlet practically any depth of water up to seven feet can be obtained. As operated, a constant flow of water through the pool is maintained during bathing hours. The bathing hours for children, for men and women patients, and for employees, are definitely fixed, and no mixing of the different classes of bathers is permitted. In the forenoon during the hours assigned to children, the flashboards are lowered to obtain a maximum depth of water of about two feet, but at other times a depth of between four and five feet is maintained.

Eight of the Rhode Island swimming pools are emptied and refilled only at long intervals, and repurification is relied upon to maintain the water in a cleanly condition. All of these pools are equipped with circulation pumps and filters, by which the water can be taken from the bottom, purified and returned to the pool. The equipment for repurification varies widely at the different pools. The circulation pumps at six of the pools are of the centrifugal type, varying in size from $1\frac{1}{2}$ ins. to 3 ins. The other two pools are equipped with duplex plunger pumps 5 ins. x 6 ins. and 6 ins. x 6 ins. respectively. All pumps are electrically driven. Seven of the eight pools are equipped with

mechanical filters of the pressure type, and one pool is equipped with open gravity filters, originally designed and operated as slow sand filters but now operated as rapid filters. Four different makes of pressure filters are represented at the seven different pools. At five of the pools the filter is in a single unit; in two cases a double unit filter is used, and in one instance a three unit filter is used. At three of the pools equipped with centrifugal pumps the capacity of those pumps was not known and could not readily be determined under the conditions which existed. At the other five pools the capacity of the pumps and filters varies from 420 gals. to 6000 gals. per hour, and the time the filters are operated varies from about one hour to twenty-four hours per day.

At seven of the pools which are operated on the continuous plan, alum is used as a coagulent whenever the filters are in operation. At the Pawtucket Y. M. C. A. alum is used only when filling the pool, and no coagulents are used at other times. Alum is also used in filtering the water for filling the pool at the Pawtucket Boys' Club. The amounts of coagulent used at the different places vary from one fouth of a grain to about four grains per gallon. At three of the pools soda is also added to the water more or less regularly, to neutralize any excess acidity caused by the use of the alum. At two of the pools where both soda and alum are used, no attempt is made to use definite amounts, and the amount actually used could not be estimated from any existing data.

As stated previously, more or less water is splashed into the scum gutters and upon the sidewalks, which does not find its way back into the pool and the replacement of this loss with fresh water is one of the factors which contribute toward the maintenance of the pool in a sanitary condition. In most cases the purifying effect of the addition of fresh water is apparently overlooked, and efforts are made to effect economies in operation by reducing the water waste to a minimum. At three of the Rhode Island pools the value of fresh water as a purifying agent is thoroughly recognized, and considerable volumes of new water are added to the pool each day.

Even with the utmost precautions to ensure the cleanli-

ness of bathers much visible dirt finds its way into the water during bathing hours. This dirt, which consists largely of epithelium and hair, settles out upon the bottom, and unless removed at regular intervals imparts a very uncleanly appearance to the pool. More or less slime also accumulates on the bottom and side walls and has to be removed at intervals. In some of the early attempts to operate pools continuously, this dirt was stirred up in the water and the filter system was relied upon to remove it, but for reasons which will be explained later this practice was far from being a success, and in modern pool practice this dirt is now removed by mechanical means.

At many pools the bottom is cleaned by long-handled brushes or squeegees, the dirt being carefully pushed forward to the outlet through which it is discharged to the sewer or to the filtration system. This is the method employed at five of the Rhode Island pools. The disadvantage of this method of cleaning is that it can never be thorough, as some of the dirt is stirred up in the water and escapes the cleaners. At three of the pools a suction cleaner is employed to remove the dirt from the bottom, which effectually overcomes the objections to the older method. As the suction pipe has to be made of considerable size in order to obtain the necessary water velocity, the apparatus is very heavy and two men are required to operate it. Because of its weight this apparatus cannot be successfully used on the side walls, and these must still be cleaned with brushes or squeegees. It has been observed that there is less trouble from growths of green slime in pools cleaned by this method, and this has been attributed to the action of the copper worn away from the brass cleaning nozzles. The effect of copper as an algæcide is well known and may be a contributing factor, but the more thorough and more frequent cleaning which these pools receive must also be taken into consideration in the interpretation of this apparent phenomena.

At four of the Rhode Island pools the bottom is cleaned every morning, two others are cleaned every other day, and two are cleaned only once a week. At the better operated pools the side walls are also scrubbed down and any floating matters on the surface of the water are flushed into the scum gutters each

TABLE 2.

STATISTICS OF PURIFICATION, CLEANING AND DISINFECTION OF EIGHT RHODE ISLAND SWIMMING POOLS.

	Brown University.	Pawtucket Y. W. C. A.	Providence Y. M. C. A.	Pawtucket Y. M. C. A.	Newport Y. M. C. A.	Army and Navy Y. M. C. A.	Woonsocket Y. M. C. A.	Moses Brown School.
Volume of Pool, Gallons	75 000	30 000	50 000	28 000	45 000	28 000	30 000	21 000
Times per week fresh water added	6	6	6	3	1	6	1	6
Gallons fresh water added each time	2 350	2 500	4 800	230	750	240	500	250
Type of Circulation pump	Plunger	Cent.	Plunger	Cent.	Cent.	Cent.	Cent.	Cent.
Type of filters*	G	N	H	J	M	M	M	J
Number of filter units	1	3	2	2	1	1	1	1
Hours run per day	12	10	24	1 2	6	4-6	12	9
Rate gallons per hour	6 000	2 [illegible]00	1 500	720	420	Not known	Not known	Not known
Alum used, gr. per gallon	0.24	0.42	0.42	0†	3.0	Not known	Not known	..
Soda used gr. per gallon	0	0	0	0	1.4	‡	‡	‡
Times per week disinfectant added	2	1	2	1	1	1	1	6
Method disinfectant applied	Bag	Bag	Sol. to surface	Bag	Sol. to inlets	Dry§	Dry§	Bag
Time applied	P.M.	A.M.	A.M.	A. [illegible]	A.M.	A.M.	A.M.	A.M.
Hypo. added, lbs. per mil. gal.	13	33	20	9	22	§	§	24
Method of cleaning bottom	Brush	Brush	Suction	Brush	Suction	Suction	Brush	Brush
Times cleaned each week	3	6	6	1	1	3	6	6

* G — Open Gravity; H — Hungerford; J — N. Y. Cont. Jewel; M — Marning. N — Norwood.

† Alum used only when filling and decolorizing the pool.

‡ Soda occasionally added directly to the pool.

§ A handful of hypochlorite scattered over surface of pool.

time the pool is cleaned. The purification equipment, and the operating and cleaning details at these various pools are shown in Table 2.

Theoretical Effectiveness of Repurification Systems.

From the foregoing we have seen that three separate agencies are employed to prevent the accumulation of dirt in the water of a continuously operated swimming pool. Two of these, filtration and the addition of fresh water, are definite quantities, and their effect individually or collectively can be expressed in definite terms for purposes of comparison. The removal of sediment from the bottom of the pool, although an important factor in maintaining the water in a cleanly condition, is not at present a measurable quantity and can be discussed only in general terms.

In the repurification of swimming-pool water by filtration, the water is taken from the pool, purified and then returned to the pool. Assuming that the purification of the water passed through the filter is complete, and this assumption is necessary for purposes of computation, the problem of determining the amount of purification accomplished in a given time becomes one of the determination of the effect of continuous dilution of the dirty water in the pool with clean water.

The effect of the successive replacement of small portions of any volume of dirty water with equal amounts of pure water may be computed by the formula —

$$D = \left(\frac{V - v}{V}\right)^n.$$

D being the porportion of dirty water remaining in the mixture, n the number of successive dilutions, V the total volume at the start and v the volume of pure water added each time. The proportion of pure water may then be obtained by subtraction.

This formula may be used directly to compute the purification effected by the addition of fresh water to a swimming pool, since this water is usually added at one time. A certain error is introduced when we attempt to use this formula to com-

pute the effect of filtration on the composition of the pool, owing to the fact that the dilution is continuous rather than intermittent. If the time intervals and replacement volumes which are taken as units are sufficiently small, however, the results obtained are sufficiently accurate for all practical purposes. The combined effect of filtration and the addition of fresh water, is not, however, the simple sum of the effect of the individual filters, but must be obtained by multiplying together the proportionate amounts of dirty water remaining after the application of each factor and subtracting the product from the original amount of dirty water. It is usually more convenient to compute this combined effect separately by the use of the formula —

$$D = \left[\frac{(V - v)\,(V - v^1)}{V^2} \right]^n$$

in which v and v^1 are the volumes of pure water introduced by the respective purification methods.

Each of the preceding computations has been based on the initial amount of dirt in the water. A greater or less amount of dirt is also introduced each day, and this fact must be taken into consideration in a comparison of the effectiveness of the repurification methods. It is impossible to determine the average amount of dirt introduced into a swimming pool by any definite group of bathers. For purposes of comparison, however, it is necessary to assume some definite amount, and the simplest method is to assume that each daily increment of dirt is equivalent to the initial amount in the pool at the time repurification was started. With this assumption the proportion of the total dirt which will be found in the water at the end of any given number of days is the average of the proportions of the initial dirt remaining in the water at the end of each successive day during that period. Under these conditions, while the percentage purification steadily increases from day to day, the actual amount of dirt in the water also increases each day. If the combined purification factors are sufficiently large, a balanced condition will eventually be obtained in which the daily purification will be approximately equal to the daily pollution, and under

the condition the pool could continue in operation indefinitely. If the repurification system is too small, however, the amount of accumulation of dirt will sooner or later become so large that the pool will have to be emptied. The individual and combined effect of filtration and fresh water addition at the Providence Y. M. C. A. for one week, computed on the assumption of continuous daily pollution as outlined above, is shown graphically in Fig. 16.

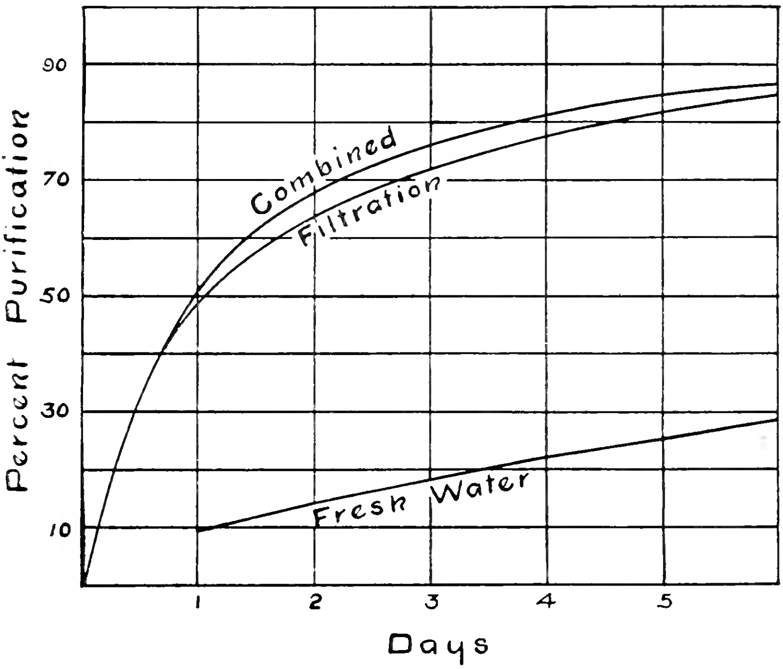

FIG. 16. EFFECT OF REPURIFICATION FACTORS AT PROVIDENCE Y. M. C. A. POOL DURING FIRST WEEK OF USE.

If the water used for filling is of high color or contains any appreciable turbidity, it is the usual practice to keep the pool closed and run the filters continuously until such time as the water has become of satisfactory appearance. Swimming-pool operators have frequently asked why it is that it takes so long

to remove the last traces of color, and why one pool can be cleaned up so much quicker than another. The answer to the first questions is to be found in the fact that the purification is by continuous dilution, and to the second that the ratio of the filter capacity to the volume of water to be cleaned up is probably very different. In Fig. 17 are shown the purification curves for one week for four of the Rhode Island pools computed on the assumption that the filters are operated twenty-four hours

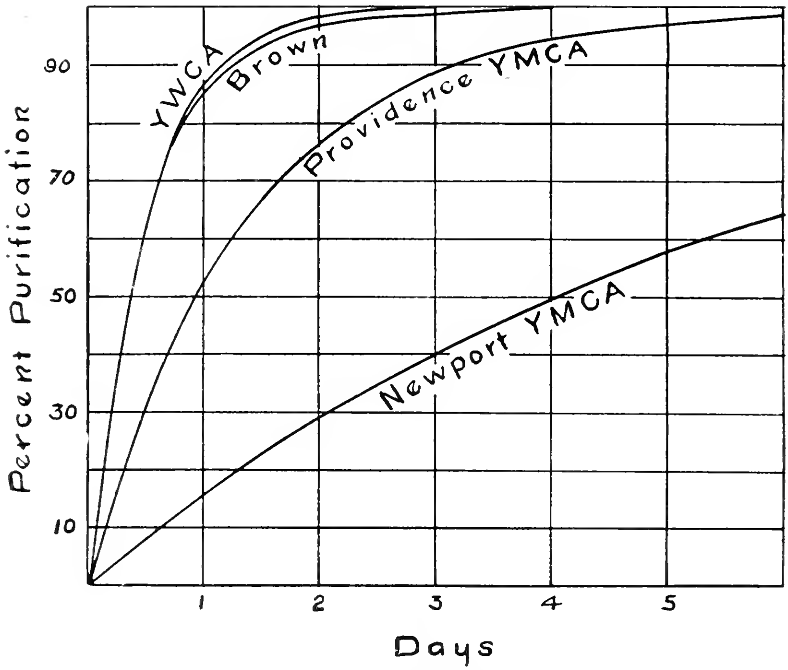

FIG. 17. REPURIFICATION AT DIFFERENT POOLS WITH FILTERS OPERATED CONTINUOUSLY TO CLEAN UP POOL.

a day to clean up the pool. The difference in the effect of having a filter equipment of generous size and of having filters or pumps which are probably too small for the size of the pool is well shown in the diagram. At the Brown and Y. W. C. A. pools it will be observed that there is a rapid improvement in

the quality of the water during the first two days and that a practically complete purification would be obtained in three to four days. At the Providence Y. M. C. A. the pumps or filters are of proportionately smaller capacity and the purification curve rises more slowly. As indicated by the curve, about a week would be required to clean up this pool on starting. At the only other two pools for which we know the rate of filtration, the proportional filter capacity is comparatively small and the

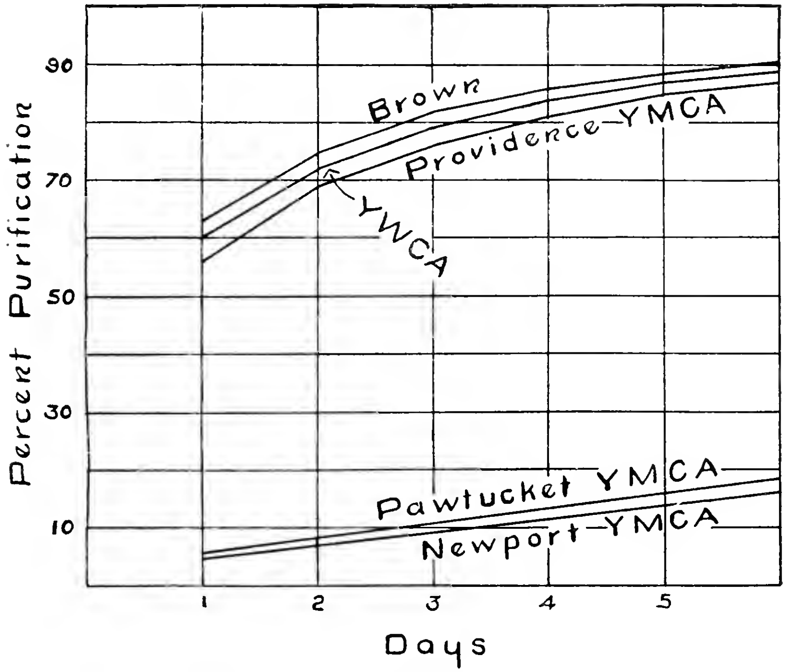

FIG. 18. REPURIFICATION OF DIFFERENT POOLS UNDER ACTUAL OPERATING CONDITIONS DURING FIRST WEEK OF USE.

purification curves rise very slowly. Two weeks or more would be required to put these pools in a satisfactory condition. The curve for the Pawtucket Y. M. C. A. pool is omitted as it is practically identical with that for the Newport Y. M. C. A. pool.

In Fig. 18 are shown graphically the combined effect of

these two purification factors as they are ordinarily applied at these five pools, computed on the assumption that constant daily amounts of dirt are introduced into the water by bathers. The percentage purification at the three pools which have adequate filter equipment and to which considerable amounts of fresh water are added at frequent intervals is observed to be high. On the other hand, the total purification is very low at the two pools at which filters of relatively small capacity are operated only a short time each day, and at which the amounts of fresh water are also very small. In Fig. 17 it was observed that the continuous filtration curves for the Brown and Y. W. C. A. pools were quite similar, with the Brown curve slightly below the other, while the curve for the Providence Y. M. C. A. was considerably lower than the other two. In Fig. 18 the combined purification curves for these three pools as operated are seen to closely parallel one another, with the Brown curve at the top. This reversal of position is caused by the fact that while a greater proportion of fresh water is added daily at the Y. W. C. A. pool, and the filter plants at both pools are relatively of the same capacity, the Brown filters are operated two hours longer each day. The rise in the position of the curve for the Providence Y. M. C. A. is due to the much larger additions of fresh water and to the fact that the filters are operated twenty-four hours a day. In the case of the latter pool, the limit of purification by filtration has been reached, while the other two pools still have a generous reserve which can be called upon in emergency. Continuing the computations for the five curves shown in Fig. 18 to the end of a year, we find that the purification for the Brown, Y. W. C. A. and Providence Y. M. C. A. pools would be 99.81, 99.78 and 99.76 per cent. respectively, while the purification for the Pawtucket Y. M. C. A. and Newport Y. M. C. A. pools would only be about 52 per cent. and 46 per cent. respectively. It is readily seen from these figures that with the high bathing loads at these latter two pools a rapid accumulation of pollution in the water must be expected under the present operating conditions.

Disinfection.

Experience has shown that it is practically impossible to control the bacterial content of the water in a swimming pool by any of the previously described processes, and at nearly all continuously operated pools some method of disinfection is employed. Hypochlorite of lime, copper sulphate, liquid chlorine, ozone and ultra-violet rays, have all been used for this purpose with more or less success. Hypochlorite is the disinfectant the most commonly employed, owing to its low cost, its ease of appliction, and its high germicidal power, and especially owing to the fact that unless used in excessive amounts it is entirely broken down in a short time and leaves behind nothing which can render the water unsuitable for bathing. Although much less potent than hypochlorite as a germicide, copper sulphate is much more effective for destroying algæ and other micro-organisms, and for this reason is of great value for the treatment of outdoor pools, and may also be used to advantage to destroy the green growths which occasionally make their appearance in indoor pools.

Ultra-violet rays, ozone and liquid chlorine are all effective sterilizing agents when properly applied to clear, low-colored waters such as are usually found in swimming pools. The chief disadvantage of each of these agents lies in the fact that it is applied only to the water in the circulation system, and for reasons discussed in the preceding chapter we can never expect to obtain a complete sterilization of the entire body of water in the pool under the conditions which ordinarily exist. In the case of ozone and ultra-violet rays, this difficulty appears to be insurmountable. In the case of liquid chlorine, however, it might be possible to obtain practically the same effect as with hypochlorite treatment if the chlorine were added in considerable excess to the water as it is returned to the pool and this overtreated water was immediately and thoroughly mixed with the other water in the pool.

At each of the eight continuously operated Rhode Island pools, hypochlorite is used as a disinfectant. The amount of disinfectant used and the method and frequency of application,

however, vary widely at the different pools. At two pools no attempt is made to use definite amounts, a handful being scattered on the surface of the water. At one pool, the chemical is dissolved in water, strained, and the clear solution sprinkled over the surface; and at another a similar solution is added to the pool at the inlet from the circulation system. At the other four pools the chemical is placed in a bag and this bag is dragged back and forth through the water until the disinfectant has been entirely dissolved. The water is disinfected at five of these pools once a week, twice a week at two pools, and every day at the other pool. At one pool the treatment is applied at night, and at all the others it is applied in the morning. The amount of hypochlorite used at each treatment varies from 9 lbs. per million gallons to 33 lbs. per million gallons. The amount of disinfectant and the method and frequency of application are shown in Table 2.

Theoretically, the disinfectant should be applied each night immediately after the bathers have left, in order to immediately destroy any infectious material present in the water. As the action of hypochlorite is very rapid there should be immediate and thorough admixture with the water in the pool, and this is more successfully accomplished by the use of the bag method described above than by the use of a solution. The practice of using dry hypochlorite on the surface should be discouraged, as undissolved particles are likely to remain on the surface of the water and affect the eyes of the bathers. The amount of disinfectant employed should be sufficient to cause an effective sterilization of the water, but any large excess must be avoided or irritations of the eyes and mucous membranes may be caused.

At Brown University the operation of the pool is supervised by the professor of bacteriology, and at the Newport Y. M. C. A. the operator received occasional assistance from the bacteriologist of the local water company. Except in these two instances the operators of the various Rhode Island pools have been working completely in the dark, with no means of knowing anything as to the effectiveness of their disinfection and purification methods, and this is also undoubtedly the situation at the majority of other pools in the East. Judging from my own ex-

perience, swimming-pool operators generally would welcome expert advice and assistance if they could obtain it, and it certainly would appear that the swimming-pool problem is of sufficient importance to warrant this advice and assistance being given through supervision by the public health authorities.

Quality of Water.

For reasons which have been stated, analyses have not been made of samples from the open-air pool at the State Sanatoruim, and from the three pools at the U. S. Naval Training Station. Both chemical and bacterial analyses were made on many samples from the other Rhode Island pools although the amount of time which could be devoted to each pool was entirely too small to fully determine the effect of individual variations in operating detail. The analytical results, however, do indicate the general effectiveness of the sanitary practice at the various pools.

The conditions in a swimming pool are extremely favorable for growths of the ordinary types of water bacteria. Growths of those types which are determined at body temperature and of B. coli have also occasionally been observed in waters where the temperature conditions were similar to those maintained in some of these pools. In any interpretation of bacterial analyses of swimming-pool water, therefore, these facts must be given due weight.

Although it is highly desirable that water to be used for bathing should be of good quality, it is the opinion of many sanitarians that the standards of purity of waters used exclusively for this purpose may safely be made somewhat lower than those for drinking water. For example one writer has proposed a standard of "not more than 10 B. coli per cc.," which would permit swimming-pool waters to contain something like two hundred times as many B. coli as are permitted in the drinking waters used on trains and boats and interstate service. As to whether such a standard is both safe and fair, and whether the same standard should be applied to all waters used for bathing whether in swimming pool or at bathing beaches are questions which demand serious consideration. This much is certain,

however, that if the quality of the water in our swimming pools is as good as that of our public water supplies we have at least provided a water for bathing which is inside the safety limit.

For the benefit of those who may be unfamiliar with the interpretation of water analyses, it may not be out of place to state here that owing to the limitations of our analytical methods it is not practicable to determine the presence or absence of disease-producing organisms in water. The types of bacteria which we include under the term B. coli, and for which we make tests, are not in themselves believed to be harmful, but being probably of human or animal origin they are used as an index by which we may measure the probable degree of pollution of a water.

In the case of four pools, the results of all analyses showed the water to compare favorably in bacterial quality with the public water supply of the cities in which they were located. In the case of five other pools, samples were also obtained at times which would pass our drinking-water standards, although at other times the water was not of such good quality.

At three of the pools samples taken early in the investigation showed very high bacterial counts. At two of these, Providence Y. M. C. A. and Newport Y. M. C. A., certain changes were made in the operating methods, and samples taken later were of much better quality. The pool at the Army and Navy Y. M. C. A. was closed soon after the first series of analyses were made, and subsequent samples could not be obtained. At five of the pools B. coli were found in 10 cc. of the water in occasional samples. In no case was B. coli detected in one-tenth cubic centimeter of the water from any swimming pool, and only in one instance, a sample from the Aborn Street Baths, was the organism found in a volume as small as one cubic centimeter. As the water with which this pool was filled gave frequent positive tests for B. coli in one cubic centimeter at this time, the origin of the organisms found in this sample is at least open to question. The results of bacterial analyses of the water from these various pools are shown in Table 3.

In connection with our bathing load figures, it was very desirable that we should have some definite information as to

TABLE 3.

RESULTS OF BACTERIAL ANALYSES OF RHODE ISLAND SWIMMING POOLS.

	Average Bacteria per cc.			Occurrence of B. Coli in Any Sample.		
	20° C	37° C				
		Total.	Red.	0.1 cc.	1.0 cc.	10. cc.
Brown University	10	3	1			0
Providence Y. M. C. A.	17 000	2	0	0	0	
Pawtucket Y. W. C. A.	150	0	0	0	0	0
Pawtucket Y. M. C. A.	32	6	1	0	0	
Newport Y. M. C. A.	17 000	2	1	0	0	0
Newport Army and Navy Y. M. C. A.	28 000	65	3	0	0	
Woonsocket Y. M. C. A.	5 500	4	1	0	0	0
Moses Brown School	380	1	1	0	0	0
Pawtucket Boys' Club	1 300	10	0	0	0	
Aborn Street Baths	13 500	30	17	0		
Lundin Baths	140	23	11	0	0	0

the amount of pollution introduced into the water by each bather. As the pool at the Pawtucket Boys' Club is refilled each Monday and the pool at the Pawtucket Y. M. C. A. is cleaned and disinfected on the same day, and as neither pool receives any further treatment during the remainder of the week, it seems probable that data on mass pollution might be obtained by an extensive study of these pools. The results of analyses of series of daily samples from these pools, however, failed entirely to yield the desired information. In both pools there was an increase in the bacterial content of the water during the first and second days of use, but no proportionate increase was apparent on succeeding days, and at the end of the week the numbers of bacteria were not unduly large. Furthermore, no regular change in the chemical quality of the water could be detected by the ordinary analytical methods.

Even after long use the water in these pools which were provided with repurification systems was, generally speaking, of lower color and better appearance and sometimes of better chemical quality than the city water which was used in filling

them. A certain increase in the soluble constituents was usually to be observed as these pools were continued in use. In one instance an increase of 50 parts per million in hardness was noted during an interval of 129 days, and in another instance the chlorine increased about 20 parts in 53 days. Increases in free ammonia and in nitrates amounting to about 2.0 parts in 56 days and 131 days were also noted, respectively. In the majority of cases, however, the total accumulated amounts of these soluble ingredients were no greater than the amounts found at times in certain of our public water supplies.

DISCUSSION.

The Brookline Swimming Pool.

Mr. L. K. Nason.* The Brookline swimming pool is the oldest municipal swimming pool in this country. It was opened twenty-one years ago January 1. Pools at that time were confined mostly to local well-to-do clubs and some few colleges. So the architect who planned the Brookline pool did not have the data which has been available for the last eighteen years, but had to obtain his information from England and Germany. That he did a good job is evidenced by the fact that the pool has stood for twenty-one years, and has never leaked. We have, within the past year, made a considerable number of changes there, but not in the pool construction itself. We have added dressing rooms around the sides of the pool and put in a new gutter. The type of pool that the architect built at that time is a type we are now building in some cases, but most of them now are entirely of concrete with an inner layer of mosaic or tile. The Brookline pool has a concrete outer shell lined with glazed bricks. Another type has a thin shell of about 6 or 8 ins., — waterproofed with tarred paper, — then a lining of common bricks, then a lining of about an inch of cement, and finally a mosaic lining placed over that. Some of the early pools were built with a patent water-tight concrete, but they did not work. The only patent concrete waterproofing is a good inspector on the job.

* Director of the Brookline Municipal Swimming Pool.

The Brookline pool, as I said, has an outside shell with a brick lining. It is in a T-shaped building, — the office being in the center of the headhouse. At the time it was built, on the right of the office was a small instruction pool, 15 ft. by 10 ft., and on the left-hand side of the door as you entered was a common shower bath in which the people of the town had a perfect right to take a shower, towels and soap being supplied free. I think Brookline and Chicago are the only municipalities which furnish absolutely free baths. We have now on each side of the pool 31 dressing rooms, and on the right upstairs we have 18 private shower baths. The pool is placed in the rear of the building. It is 26 by 80 ft., and is 4 feet deep at its shallow end and $7\frac{1}{2}$ ft. at the deep end. Whether or not steps are needed depends a good deal on what the pool is to be used for. I believe where women and girls are to use the pool, one flight of steps should be placed at each end. Where only men and boys use the pool the steps can be omitted. The pool has an overflow gutter around the four sides of the tank. The water enters at one end and goes out at the other. The tank holds 75 000 gals. of water, which is obtained from the town supply, and is heated by an injection of steam as it passes in through a pipe. The water is filtered by three Norwood filters. There were two reasons for choosing the Norwood filter. One was that it has three units independent of each other. If one breaks down, you still have the other two. The main reason is simply that when you have cleaned out the tank with the Norwood filter and have used the water that is in the pool, it thereby gives you the opportunity of replacing the water in the pool with fresh water, so you can keep your pool water much livelier and add fresh water much oftener than if you use a one-unit system, where you have to use fresh or city water to clean your filters. The pool as it stands cost some $65 000; $50 000 when it was first built, and $15 000 for renovations. There has been an attendance of over 1 662 000 since operation started. We have a lot of swimming events at Brookline, and at one end of the pool we have an opportunity to put up bleachers on which we can seat 600. There is now an 8-in. walk all the way around it, and there is a coping around the edge 14 ins. wide and 6 ins. above the floor, so that no water, after it splashes, can go back.

The matter of operation has three distinct features, depending entirely upon the size, the type of people who are to use the pool, and where it is located. The size of a pool makes it easy or extremely difficult for those who use it to keep it clean. It is fairly easy for a college or some well-to-do club to keep its pool clean, because the type of people who use it have some idea of personal hygiene, and when a notice is put up to remove clothing and take a shower bath using soap, — they will obey the rules; but where a pool is to be used by a municipality where they have from 400 to 600 youngsters a day, and people from the section of the town where they do not believe in hygiene, — it is another problem to enforce the regulations. So a constant supervision of the pool is necessary if you are to obtain results which will be satisfactory. We will not find that in a pool which is catering to the boys or people of the slums, it will be possible to keep the bacteria down to such a low figure as in that of a well-to-do club. In our pool at Brookline we have on some days from 400 to 500 youngsters, the next morning we will have 100 to 150 women from the best section of the town. Our problem is not only to keep the pool in shape for the youngsters, but also for the esthetic women who come from some of our well-to-do homes, and who feel that the slightest bit of dirt that can be found is a subject for complaint. Efficient supervision, to my mind, is the greatest factor in keeping a pool sanitary. You may have all the appliances you can buy, — you may make a study of how best to disinfect the pool, how to use the filters, how to keep the water at a certain temperature, — and yet, if you have no person on your staff who is very much interested in the swimming pool, you will find it will degenerate at least thirty per cent. and the results you reach will be far short of what you expected. We keep the water at a temperature of from 75 to 78 degrees Fahr. The temperature of the room has to go up naturally with the temperature of the water, so the temperature of the room is 70 to 80 degrees at Brookline.

The department owns every suit and every towel, and no outside ones are allowed. Shoes and stockings are not allowed, but we insist that women shall wear caps. A cleansing shower

bath, with soap, is required of every one before entering the pool. Concerning our particular pool, it is used by an average of 200 to 300 a day, and last August, on a very hot day, over 830 people used it. So it is some little problem to keep the pool sanitary for the next morning, when the women come. By the constant use of disinfectant and by constant vigilance, we have been able so far to keep the bacteria very low. That is something I do not have to bother about much, because our town board of health maintains a rigid inspection, and if it finds that anything is wrong it is reported to me at once. I recall that when we changed our pool we had a foot of water less for two days. I experimented to see if we had to add more disinfectant, and the inspector of the board of health reported to me that the number of bacteria was just a little higher than it ought to be. I was very much interested in the figures thrown on the screen showing the effect of adding disinfectant. At Brookline we have 75 000 gals. of water, and we add 2 lbs. of chloride of lime each night. It is done by the old-fashioned method of putting it in a bag, which our janitor drags over the surface. I have looked into the matter of the ultra-violet ray and chlorine tanks, and I am perfectly satisfied, as long as our board of health does not object, to use our own system, because our janitor has orders to use only 2 lbs. of chloride of lime each night, and as that is all he is given, I know it is used. The average man in a janitor's position does not realize the importance of a matter of this sort, and some night he might forget; so each week our man is apportioned his 12 lbs. of chloride of lime, and each day that is checked up to see that 2 lbs. have been used. We use 2 lbs. of alum per day. At Brookline, when the pool was first built, it was emptied every two weeks. Then, as it was impossible to keep the bacteria below the danger point, it was emptied every week, and finally each night. That was done for five or six years, at a cost of about \$4 200. To-day we empty it every two weeks. When we emptied it each night we could not see the bottom of the pool. It takes now three days to clear out our pool so that you can see the bottom. Our filters have a capacity of 75 000 gals. every ten hours, and that is the capacity of our pool. Our filters are never shut down. We continually add fresh water.

We have a small water tank into which steam is played, and from which a pipe leads directly to the alum accumulator tank. That enters the tank and passes from the tank to the water going into the filters, so we have a one-inch pipe flowing into our pool all the time.

The overflow gutter is a good thing when used as it should be. But to be of service the water must be continually kept at the edge of the gutter. The thought I have of the gutter is that when a man dives with a splash, the water should go into the gutter.

Regarding the adding of fresh water, as I said, the cleaning of our filters is done every morning. It takes about a foot of water out of our pool to clean our filters as they should be cleaned. So you see our pool is filled actually oftener than every two weeks. On Tuesday and Thursday afternoons, when we have the little fellows in, our pool is dropped down eighteen inches below the top. Then it is brought up to the top, so we use a foot and a half of water on these two days.

One of the greatest troubles we had with the old pool was that so many people got cold after using it, as they had to dress in the same atmosphere that they took a swim in. That is one of the reasons why we took our dressing rooms from the side of the pool. They are now kept at from 65 to 70 degrees, so that after a person leaves the hot room he does not have to dress in such a hot atmosphere.

Fig. 19 shows the hair-drying room, and Fig. 20 gives a general view of the pool. A suction motor takes hot air from the closed radiator below, and passes it through 2-in. pipes. That is something I have worked out myself, and it is very satisfactory. Where you have to handle women and girls in the winter time, some arrangement must be made to dry their hair.

A water suction system, furnished by the Sanitary Dust Removing Company, has been installed to remove the dirt which is bound to accumulate on the bottom of the pool. This is done every morning before the pool is used at all. Then every two weeks the pool is emptied and washed with acid. The brush sucks up the dirt from the bottom. This is done at the same time that the pump sucks the water up. The bottom is

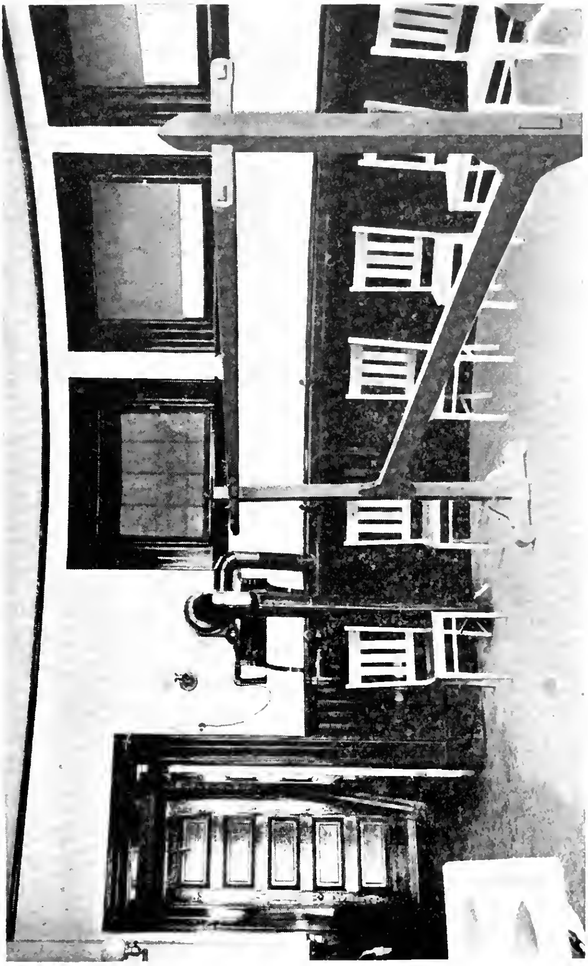

Fig. 19. Brookline Swimming Pool. Hair Drying Room.

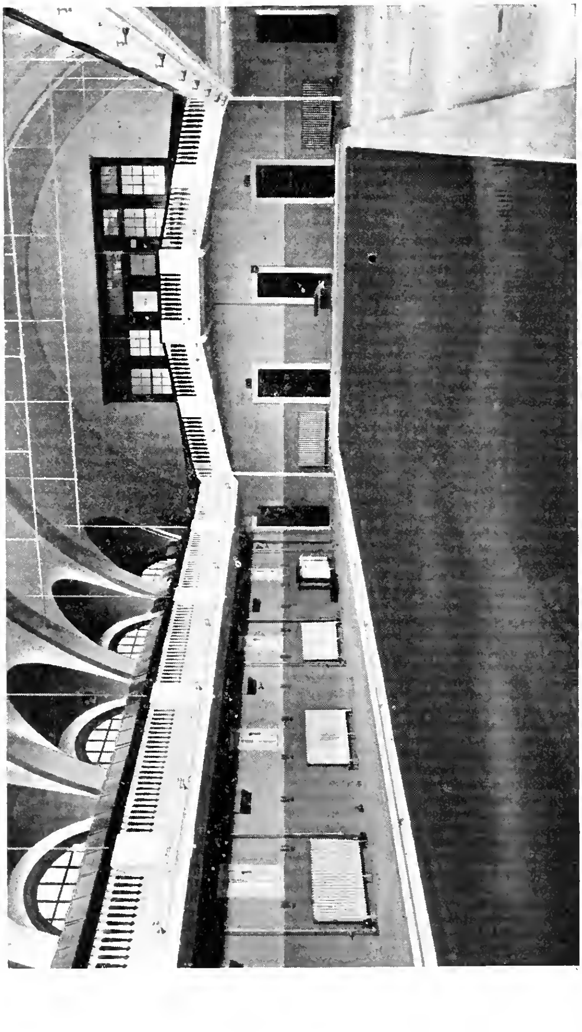

Fig. 20. — Brookline Swimming Pool.

concrete, with mosaic tile over it. You will find some pools now with cement bottoms only, which is dangerous from the fact that you cannot see the bottom. That is the reason we put in the filter at Brookline, because of the danger of somebody drowning. Where we handle from 600 to 800 a day, it means that we must be constantly on the alert to see that youngsters do not get drowned. Some people have said: "How can you handle 800 people in one day in a swimming pool 26 ft. by 80 ft.?" We do it by having half-hour periods. On each side of the entrance to the building there are two dressing rooms. It is arranged so that while the boys or parents are undressing or dressing on one side, those from the other side are in the pool. We run half-hour periods. At ten minutes of the hour we let in one side. On the hour the other side comes out. We allow ten minutes for the boys to undress and get ready to enter the pool. We have a rigid law there in regard to boys especially and small girls, — that they must present themselves to an attendant who must pass them before they can enter the pool. For the women and men we have a period of forty minutes, which is the longest allowed. I feel that that is long enough for anybody. There have been since the pool was opened, twenty-one years ago, 1 668 000 people in attendance although not all have used the pool, because a large number of people use our bathhouse and take shower baths. I will give you last year's figures; so that you can perhaps see what proportion use our pool. The number using the swimming pool last year was 65 073. The number taking shower baths and not using the pool was 17 797, —making a total attendance of 83 879. The number of residents who used the pool was 61 000 and the number of non-residents 4 073. The number of three free lessons given to the people of Brookline was 5 365. Eighty-five per cent. of the children of Brookline know how to swim, and we are now taking them as young as eight years of age and giving them free lessons, because I feel that if a boy graduates from the grammar school without knowing how to swim, the chances are that he will not learn to swim. The number of lessons given last year was 1 975, and the receipts \$4 272. It is pretty hard to give the expense of the department because our swimming pool and

gymnasium department are run as one department, — but I figure it at about $16 000. For the gymnasium and bath department there was appropriated last year $29 200. The pool in Brookline is used by people from nearly every section of the town. We have to make different arrangements so that each section of the town can be reached. We have free periods and five-cent periods for the children, so that the poor boy has just as good an opportunity of using our pool as the rich boy. In the morning it is nothing unusual to see twelve automobiles before our swimming pool, and on Friday night, which is given over to men only, you will find 35 to 70 men in the pool. We use a small trunk for men and a one-piece loose suit for women, made from our own designs. As I said before, we are kept constantly on the alert to keep up the standard of the pool, and I have one man who sees that the rules of the department are carried out and that our rooms are kept clean. By giving him the power to carry on the department under my supervision, we obtain results. When we had the infantile paralysis scare the question came up of closing our pool. The board of health said, "No, that is one of the best assets we have," — so we kept it open. During the twenty-one years it has been open there has never been any epidemic of any kind. It is a constant problem to keep it clean; yet when one is interested in it, although he may not be able to keep it perfectly clean, he can keep it in shape where it will not be dangerous to the health of people.

Mr. Scaife.* — We are building a very large pool, — a pool that will hold 130 000 gals. of water. At Hartford, Conn., where I have been for the last five or six years, we have been using the liquid gas with apparatus made by the Wallace and Tiernan Company of New York, that dispenses the chlorine automatically. Our circulating pumps were circulating water at the rate of 100 gals. a minute. That meant that we needed a drop of gas every sixty seconds. We circulated the full contents of the pool every twenty-four hours, and after six months' use, with an average of 300 to 400 a day using the pool, specimens of water taken at six o'clock and one at night showed sixteen bacteria per cubic centimeter and absolutely no colon

* Director of Physical Education, Worcester, Mass., Y. M. C. A.

bacilli whatever. At the Waterbury pool, disinfected in the same manner, after six months' use by women and children, it showed absolutely no bacteria whatever from the tests. The beauty of the liquid gas is that it works automatically. You do not have to depend on the janitor to see that your chlorine is properly mixed, and from my experience I think it is a wonderful apparatus.

FREDERIC BONNET, Jr.* — In our work at the Worcester Boys' Club and at the Worcester Academy we began with a clean pool and fresh water. The accompanying diagram, Fig. 21, shows the results obtained at the Boys' Club. The pool was emptied on February 20, and you will note that the bacteria rose to about 175 000 in three days. They then diminished toward the end of the week. This is the accustomed curve for a pool using no disinfectants. On the 26th, 3 ozs. of copper sulphate were used every day with very little effect. About March 3, there was a decided drop to about 100, then there was a rise although we changed the application of the copper sulphate by treating on alternate days with 6 ozs. The increase was slight but tended to remain constant at about 1 000 bacteria per cubic centimeter. On March 12, common salt was added to the pool, so that the chlorine in the pool was 50 parts per million. This helped the copper sulphate in a very surprising way and practically gave us a sterile pool for some time. About April 7, however, certain types of bacteria began to develop and there was a rapid increase in the number of bacteria present. We therefore decided to use a small quantity of bleaching powder to get rid of these aftergrowths, and in this, as you see, we were quite successful. The curve for the Worcester Academy corresponds perfectly with that of the Boys' Club. You will note by this alternating treatment of copper sulphate and bleaching powder that the amount of bleaching powder which was necessary to give a sterile pool was very much less than would have been the case had the bleaching powder alone been used. During the past year Worcester Academy has been operating their pool along this line, and we have been making weekly bacterial counts, and the pool has been kept in practically a sterile con-

* Professor of Chemistry, Worcester Polytechnic Institute, Worcester, Mass.

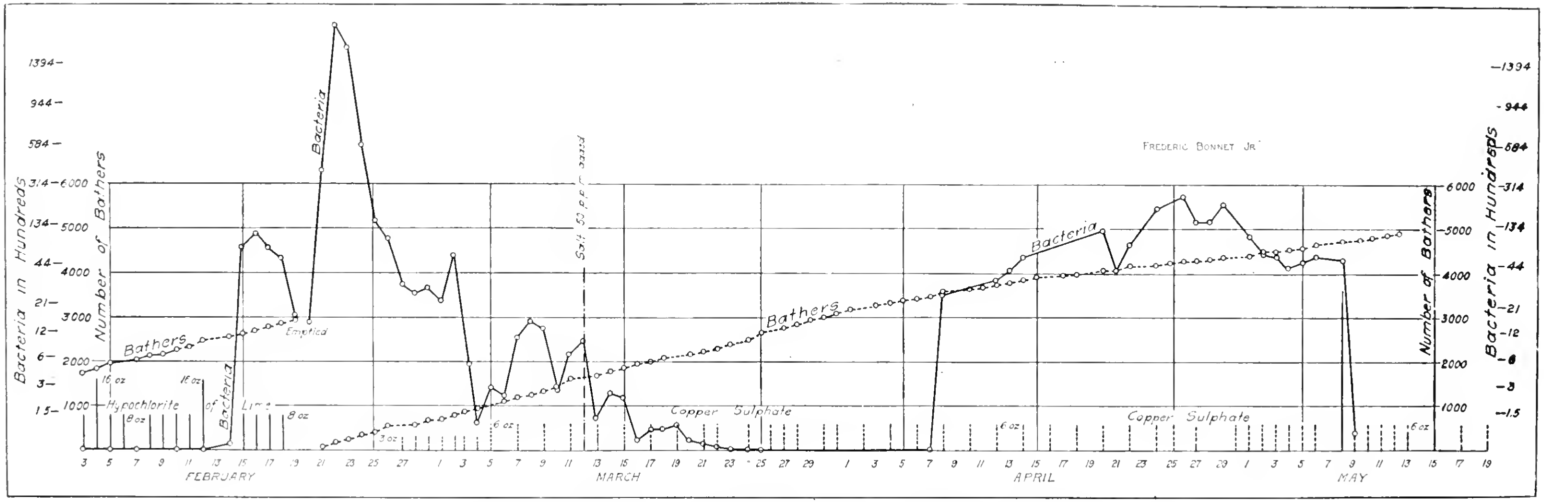

FIG. 21. ANALYSIS OF WATER FROM SWIMMING POOL AT WORCESTER BOYS' CLUB.

dition, occasionally the number of bacteria rising to 100, but for most of the time the plates are practically sterile. One interesting matter in connection with the Academy pool was the disintegration of the cement which held the small tile in place. Owing to the treatment of the water, this disintegration was laid to the chemicals which had been added to the water for sterilizing purposes. Further investigation showed that this disintegration would have proceeded even without the sterilizing chemicals. Further investigation shows that, in placing the tile, cement had been used without waterproofing. The most important point in the construction of the pool itself is to build it with waterproof materials, so that the water may not penetrate behind the tile, dissolve the bonding material and thus loosen the tile. If properly waterproofed this cannot take place. The pool was drained, all the cement was taken out as far as possible, with a wire brush, and the spaces replaced with waterproofing cement, and so far as I know has stood out very well since that.

Answers to Questions Propounded by Swimming-Pool Operators.

1. Why, when and how much alum should be used in treating the water in a swimming pool?
2. Why, when and how much alkali (soda ash?) should be used?

   The amount of alum which should be used depends upon the quality of the water used. If the water is hard, due to bicarbonate of lime (alkalinity), a good precipitate will be formed with a small amount of alum. If the hardness is due to incrustants ($CaSO_4$) it becomes necessary to add soda ash to give a proper precipitate.

   One grain per gallon of alum requires at least 7.7 parts per million of alkalinity to give a precipitate, or 1 grain per gallon of alum requires 8.2 parts per million of soda ash equivalent to 68 lbs. per million gallons.
3. How can growths be controlled?

   Growths can be controlled by cleaning pool and scrubbing down walls with a solution of copper sulphate before refilling pool.
4. Why does heating the water for the pool cause growths in a pool lighted only by electricity (if such is true)?

   (The growths are not specified — Growths develop in an ice-box drain which may be in the dark.)
5. How can dark-colored water be made clear?

   Dark-colored water can be made clear by treatment with alum (very small amount) or alum and soda ash (see 1 and 2), settling, filtering, or both.

6. How often should the water in a pool be changed?

This depends upon the individual case — and I should say "when it needs it."

7. How can stains on the tile floors, coming from the bathers' feet and the use of rubber mats, be removed, or prevented?

Sometimes by scrubbing spots with a little muriatic acid.

8. What disinfectants give the best satisfaction in keeping the water free from pathogenic bacteria and at the same time being odorless, tasteless and harmless to the eyes and skin?

Ozone — see Public Health Reports, March 1, 1918.

9. What is the best method of keeping the bottom and sides of the pool clean?

Scrubbing with a weighted brush daily and giving a thorough scrub when pool is emptied.

LEVI H. GREENWOOD.* — The swimming pool in Gardner resembles the Brookline tank in its arrangement very much. We have also an outside pool about 100 yds. across in one direction and 80 in the other. It is located on the bank of a pond which is the town water supply. Across one end of this pond runs a railroad track dividing one part of it from the main town water supply. This little bay was gradually drying up and being filled up when we took it and decided to build a bath house there, — dig the pond out and make an outside swimming pool. We had to take out from four to six feet of muck all over the pond. We took it our with tip-carts, and to get the balance of it out, tried to blow it out with fire hose and finally took it out with wheelbarrows. Altogether we expended about ten thousand dollars on the cleaning out of that pond and calking the bottom with gravel, grading and sodding the banks. In the summertime we use that for bathers in the daytime and the inside one in the evening. We have been bothered very considerably ever since we started, by the growth of algæ. That is the only trouble we have had with it. The algæ grows and forms clusters or gobs, which float around in the water for about ten days in the early part of the summer. Then that disappears. We have tried everything we can think of to get rid of that condition, which is not at all dangerous, but decidedly unpleasant to bathers. Of course we use hypochlorite of lime for the bacteria and copper sulphate for that vegetable growth,

* Trustee, Gardner, Mass., Municipal Swimming Pool.

and while that helps the matter somewhat it has not yet cured it. After ten days or so we get rid of it, — whether it dies a natural death or whether its death is mostly caused by copper sulphate I am not sure. Of course we shall never get a clear water in the outside pool such as we have in the inside pool, because it is not filtered water and the natural supply is not as clear as filtered water, but we would very much like information as to how we can overcome the growth. We are bothered by an algæ growth even in the inside pool, which will begin to discolor the tank in about five months despite the vacuum cleaner.

MELVILLE C. WHIPPLE.* — The paper presented by Mr. Gage is a valuable contribution to the sanitation of swimming pools, both because of the information it includes and because of the new angles of approach to the problem which he has employed. It is to be hoped that he will be able to carry his work further, to the limits which are justified by the new methods of study. In the meantime it will be profitable for others to make appliction of some of the suggestions given in Mr. Gage's present paper.

During the past two years the swimming pool at the Cambridge Y. M. C. A. has been under the inspection of the Laboratory of Hygiene and Sanitation at Harvard University. Special studies have been carried on by research students, and regular inspections have been made from the laboratory. Through the courtesy of Mr. Waters, physical director, I have varied the system of sanitary control from time to time, with the result that the present procedure is more effective and more easily carried out than that formerly used.

Operation of Cambridge Y. M. C. A. Pool.

The natatorium at the Cambridge Y. M. C. A. is a modern one, well lighted and equipped with a pool 20 by 60 ft. holding 53 000 gals. A high curbing surrounds the pool and a trough at the water's edge carries off drainage from the curb and expectorated material from the bathers.

The source of the water is a driven well 400 ft. deep. The water is hard, colorless and clear, but contains ordinary forms of

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bacteria to the extent of several hundred per cubic centimeter. In series with the pool is a centrifugal pump, handling 50 gals. per minute, a pressure filter containing sand, and a heater. Circulation and filtration is maintained about eighteen hours each day. A vacuum cleaning apparatus is used to eject accumulated balls of hair and lint which collect at the bottom.

Men use the pool without trunks or clothing after they have taken a shower bath. On one or two days a week during certain hours women are given the use of the pool. They wear suits provided by the institution. The heaviest contamination has been found to occur on these days. In warm weather the daily attendance of men reaches one hundred or more, in cold weather it is somewhat less than this.

Filtration and the Use of Alum.

Like most pressure filters the one installed was designed to make use of potash alum as a coagulant for the water. Mr. Gage has described the alum pot and the way in which a small stream of water is by-passed through it to dissolve the alum and carry it to the water entering the filter.

At the time studies were first undertaken, a weekly dose of potash alum of 30 lbs. per million gallons was being added to the alum pot. This was continued for a time while disinfection experiments were made, but the water in the pool was at all times slightly opalescent or cloudy. The bacterial efficiency of the filter was not very great, varying from 20 per cent. to 60 per cent. Experiments were then made *without* the use of alum and it was found that the appearance of the water was much improved, and the efficiency of the filter was not noticeably affected. On the basis of these experiments alum treatment was discontinued and none has been added for two years.

This procedure is obviously out of the question when surface waters are used as it is then desired to remove the color and clear the water, but it is practicable for well waters. When alum is used there is not time for coagulation before the water passes to the filter. It occurs later in the pool, and produces a noticeable turbidity.

The Use of Copper Sulphate.

Disinfection was formerly carried out at the Cambridge pool by means of chloride of lime, added in the proportion of 20 lbs. per million gallons on every other night. The results were fairly satisfactory measured by bacteriological standards, but there were occasional complaints of taste in the water and irritation of mucous linings. The latter were no doubt stimulated by the occasional odor of chlorine in the natatorium and by its taste in the water.

A long series of experiments were made with copper sulphate. Not only was it desired to restrain bacterial growth in the pool, but some method of controlling algæ growths was sought. Algæ chiefly diatoms, were frequently troublesome by growing on the white tile and forming unsightly brown patches. Copper sulphate proved a cure for this condition. Its use has also maintained a satisfactory bacterial content, the number of 37 degrees Cent. (organisms varying from 0 to 10, and the 20 degrees Cent.) organisms from 1 000 to 40 000 per cubic centimeter when the proper dose was applied. B. coli, the intestinal bacterium, is almost never found.

For over a year copper sulphate was added three nights each week in the proportion of 1.1 parts per million, or about 9 lbs. per million gallons. Recently the dose was increased to 0.9 parts per million, or 7.5 lbs. per million gallons, each night. This was found to still further reduce the number of bacteria growing at 20 degrees Cent. This small amount — about 0.4 lb. — is hung in a cloth bag over the outlet from the pool, and is dissolved while the water is being circulated.

At one time the copper sulphate was put into the alum pot of the filter. When it became necessary to replace the pot with a new one, the bacterial content of the pool increased rapidly. It was found that the cast-iron alum pot became choked with a brown mud, which was 75 per cent. metallic copper. Consequently the copper was not available for disinfection. This displacement of copper from solution by means of iron is a point to bear in mind when copper sulphate is used. It should not be put in iron receptacles to dissolve.

The water in the Cambridge pool has not been drawn off

for about fifteen months, and during that time has been kept in a satsifactory condition, as evidenced by a large number of analyses. The tile is clean and the water clear and of satisfactory bacterial content. With surface waters it is possible that copper sulphate may not be an acceptable disinfecting agent, but with well waters it may be used and has the following advantages:

1. It does not deteriorate or lose strength in storage.
2. It is odorless and tasteless in the quantities used.
3. It is easily handled and weighed.
4. It prevents the growth of algæ in pools and on the tile.
5. It is precipitated finally by the alkalinity of the water and tends to accumulate on the sand of the filter where it exerts a further bactericidal effect.
6. It apparently exerts a selective action upon the forms of bacteria growing at a body temperature, 37 degrees.

Beneficial Effects of Flushing.

There is a considerable volume of water lost from a pool each day from splashing and evaporation. In a week this may amount to a depth of one foot. The restoration of this loss by means of fresh water is a great factor in maintaining proper hygienic conditions. It is advisable to add fresh water as often and in as large volumes as possible, but economic considerations will generally be found to govern this. At the Cambridge pool it was formerly the custom to add about 8 000 gals. each day, but during the past year this has been reduced to about 10 000 gals. each week, owing to a scarcity of well water. Nevertheless the condition of the pool has been quite satisfactory.

When water is added, the level should always be brought to the edge of the trough and allowed to overflow. Analyses have shown that the surface layers of a pool which has been allowed to stand quiet over night contain considerable floating material and a bacterial content much higher than the water at a depth of one foot. It is thus possible to " skim " off this dirtier water. If circulation with a pump is maintained over night the surface accumulations of dirt and bacteria will be less, but will still occur.

The points brought up in this discussion did not originate from work in connection with a large number of pools. In fact, they were suggested from the operation of only two pools, but they are presented here with the hope that they may prove valuable or suggestive to those operating pools under conditions comparable to those described.

Answers to Questions Propounded by Swimming-Pool Operators.

1. Why, when and how much alum should be used in treating the water in a swimming pool?

Alum should only be used in swimming pools when the water is subsequently filtered to remove the precipitated aluminum compound. Some waters do not require alum. These are the clear, colorless waters from underground sources. When coloring matter or turbidity are present in the water, alum will remove these as the contents of the pool are filtered over and over.

From 0.25 to 1.5 grains per gallon, or 36 to 215 lbs. per million gallons, of potash alum will be required to properly clear the water. The actual quantity used is based upon the capacity of the pool and is added to the alum chamber of the filters. There it dissolves slowly as the water circulates through the filters. The dose may be repeated weekly, or more often according to the rate of filtration and the appearance of the water.

2. Why, when and how much alkali (soda ash?) should be used?

Soda ash need never be added to a swimming pool unless alum has been added in such an amount as to neutralize the natural alkalinity. Artificial alkalinity is then supplied by the soda. Each grain per gallon of alum neutralizes 7.7 parts per million of natural alkalinity. If it is desired to supply alkalinity with soda ash, one part per million of alkalinity will be supplied by every 8.8 lbs. of soda added to each million gallons.

3. How can growths be controlled?

If by growths, algæ are meant, these are easily controlled by the addition of copper sulphate. This substance is an excellent algicide, and also a good germicide, if the water contains only a slight amount of color and turbidity. Chloride of lime is not efficacious and reliable for keeping down these growths. Pools regularly disinfected with chloride of lime have exhibited growths of algæ on the tile.

In the treatment of the Cambridge Y. M. C. A. pool 0.9 parts per million of copper sulphate is added each night, and this serves to prevent all growths of algæ and to disinfect the water in a satisfactory manner. About one part per million is the average dose used in the treatment of water-works reservoirs.

4. Why does heating the water for the pool cause growths in a pool lighted only by electricity (if such is true)?

Heating the water would only cause growths of algæ by virtue of raising the temperature of the whole pool to a point which might provide optimum conditions of growth. There is a critical temperature for all species below which they do not readily reproduce.

5. How can dark colored water be made clear?

Dark-colored water is usually made so by the presence of vegetable coloring matter. This can be removed by treating with alum and filtering as described under Question 1. It is not advisable to use deeply colored water if any other source is available, for the task of maintaining an efficiency of filtration which will produce water of a satisfactory appearance in the pool is seldom possible of accomplishment.

Filtration without the use of alum will remove only a small portion of coloring matter.

6. How often should the water in a pool be changed?

The expense of emptying and refilling the pool and the amount of inconvenience encountered by reason of not having the pool available for use during this process will determine the frequency of change. It goes without saying that as much fresh water as possible should be added. A continuous stream of clean water flowing through the pool is the ideal condition.

If the water is not disinfected it should not remain in the pool longer than one week with perhaps 50 to 75 bathers each day. Even then the dangers from contamination are greater than would be the case if disinfection was practiced and the water allowed to remain for two or three weeks. Disinfection should be practiced in all pools not subject to a continuous flow of good water.

If filtration and disinfection are both practiced, and the quality of the fresh water is good, then refilling may be postponed for many weeks or months, if a considerable volume of fresh water, say one eighth to one fifth the capacity of the pool, is added weekly. Nearly every pool is a law unto itself in the matter of bacterial contamination. Analysis alone will show the true conditions, which will vary with the "bathing load" and the character of the water used.

7. How can stains on the tile floors, coming from the bathers' feet and the use of rubber mats, be removed, or prevented?

Rubber mats are a source of annoyance from gradual disintegration and from the collection of dust on their rough surfaces. They require frequent scrubbing with plenty of water. Stains from them are best removed with a strong solution of soap powder, or with gasoline.

8. What disinfectants give the best satisfaction in keeping the water free from pathogenic bacteria and at the same time being odorless, tasteless and harmless to the eyes and skin?

Bleaching powder, chloride of lime, is an efficient disinfectant

and totally harmless in the quantities required. A slight odor or taste is often apparent when it is used in waters containing no organic matter to absorb the slight excess necessary for disinfection. The use of copper sulphate has met with success in the treatment of such waters. (See discussion submitted by M. C. Whipple.)

Ozone and ultra-violet light have been used to a limited extent. Their installation is rather expensive, more complicated to operate and not suited to all waters.

9. What is the best method of keeping the bottom and sides of the pool clean?

The vacuum brush will keep the bottom and sides of the pool clean if used each day or two. It stirs up the dirt and sucks it out in a stream of water. Hydrochloric or oxalic acid may be used in dilute solution to remove stains from the tiling when the pool is emptied.

R. S. WESTON.* — In the matter of bathing in ponds used as sources of water supply Dublin Pond, in the Monadnock region, may be mentioned. This is a beautiful sheet of water, about half a mile in diameter and perhaps 60 ft. deep. It is used as a source of water supply and a general place of recreation for the cottagers surrounding it, some of the cottages being of large size and containing a great many residents in summer. They use one end of this pond as a bathing beach. They take great pains — they have an association — to prevent any pollution of the lake, and at the time I visited it and made an inspection, — which was some four or five years ago, — there was only one possible source of pollution. Most of the intakes for water were in 20 ft. of water and about 100 ft. or more from shore. They have a very good laboratory there, run by a local physician and supported by the cottagers, which keeps control of the milk and water supply. They found that in depths of 20 ft. or more the water was practically free not only from sewerage bacteria but from all bacteria that would ferment, — i. e., in any way relating to intestinal bacteria. So when the question was asked us what they should do with their water supply, we felt that if they would place their intakes at a depth of 30 ft. they could still use that water for drinking purposes. Regarding the use of a pond for a swimming pool, I should want, in giving advice of that kind, to know my pond; but to use it as a source of ice supply — cutting the ice six months after it

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ceases to be used as a swimming pool — I think it would be entirely without objection. In the first place we have the element of time there. The bacteria decrease very rapidly — particularly disease bacteria — in water rich with flora. In water of that kind animalculæ grow, and these will feed on the bacteria and reduce the number very rapidly. In thirty days' time it is doubtful if any considerable number of disease germs remain according to experiments which have been conducted; and if the water is to be used for general recreation purposes and for bathing in summer and then allowed to rest during the fall, there ought to be no reason why it would not be all right in the winter.

The Construction and Sanitary Control of Swimming Pools in Massachusetts.

Frank A. Marston.* — In order that this discussion might be supplemented by a résumé of the practice in construction and operation of swimming pools in Massachusetts, blank forms were sent to a number of institutions operating pools. Replies have been received in regard to 34 pools, and the results are summarized in the following paragraphs and in Tables 4 and 5. The pools vary considerably in construction and methods of operation. The data are instructive, as indicating the present state of the art in this vicinity, and the replies received indicate that the majority of the operators are anxious to maintain sanitary pools and are willing to receive assistance in accomplishing that end. No attempt was made to collect data regarding the "plunges" or small pools, of which there are many.

Construction.

Shape. — The pools listed in Table 1 are rectangular in plan, varying in length from 28 ft. to 100 ft., twenty-two of them being 60 ft. or over in length; and varying in width from 18 ft. to 30 ft.

Depth. — The maximum depth is, in most of the pools, at least 7 ft., and the minimum depth at the shallow end is in the

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vicinity of 3 ft. 6 ins. Where a spring-board is used, the maximum depth is located from 10 to 15 ft. from the end at which the board is attached, in order to bring the deep water where it is needed for diving. The bottom slopes from either end to the deepest point, thus facilitatng the draining and cleaning of the pool.

Location of Inlets and Outlet. — In the well-designed pools the inlets are distributed across the shallow end near the top, and the outlet, usually only one, is at the bottom in the deepest section.

Spit Troughs. — The general opinion expressed was that there should be a spit trough extending around the pool on all four sides. This trough should be designed to serve, also, as a handrail and an overflow and splash trough. It should not project out into the pool on account of the danger of the bathers striking it when jumping into the pool. It has been suggested that there should be provision for automatic, periodic flushing of this trough, to prevent the occasional washing back of the contents into the pool by a wave.

Walk Drainage. — The walk about the pool usually has a raised edge to prevent water dripping from the bathers or dirt from the feet from entering the pool. Some means of automatically flushing this surface into a drain or into the expectoration troughs has been suggested as a needed improvement. Objection to the raised edge on the walk has been made on account of the danger of bathers tripping over it.

Materials of Construction. — All of the pools are constructed of concrete with white tile lining on the sides, the bottoms being lined, for the majority, with white tile, marble or mosaic. It is essential that the pools be water-tight, and to this end special precautions should be taken in construction.

Location of Pool. — Too often it appears that a pool is located in the basement space remaining after all other purposes have been served. Many of the operators mentioned the desirability of locating the pool so that daylight is available during the day, for lighting the room, and there is ample ventilation to the outside air.

Some operators expressed the opinion that direct sunlight

TABLE 4. — DATA RELATING TO SWIMMING POOLS IN MASSACHUSETTS.

Location.	Dimensions of Pool in Ft.				Approximate Capacity of Pool in Gallons.	Source of Water Supply.	Frequency of Emptying per year.	Hours per day Circulation Pump Operated.	Average number of Bathers per Week.	Capacity of Pool in Gallons per User per Week.
	Length.	Width.	Max. Depth.	Min. Depth.						
Amherst College, Amherst	75	22	7.75	4.75	75 000	Munic.	2–3	5–7	800	94
Beverly Y. M. C. A.	40	20	8	3	40 000	Munic.	1	12	450–500	84
Boston Athletic Association	40	30	7	. .	45 000	Munic.	13	24	100	450
City of Boston—Curtis Hall	75	25	7	3.5	75 000	Munic.	12	24	8–2 000	37
City of Boston—Columbia Road[3]	40	30	4	4	20 000	Munic.	104	. .	200–1 000	33
City of Boston—Cabot Street[3]	75	25	7	3.5	75 000	Munic.	104	. .	300–700	150
Boston Y. M. C. A.	75	25	7.5	3.5	78 000	Wells	13[6]	18	860	91
Brookline Municipal	80	26	7.5	3.83	75 000	Munic.	26	24	1 150	65
Cambridge Y. M. C. A.	60	20	7.5	3.5	53 000	Well	1 per 14 mo.	18	1 200–1 500	39
Dean Academy, Franklin	50	20	7.5	3.5	43 700	Munic.	2	5	100	437
Framingham Civic League	75	25	7.5	3	{89 000[4] 68 000	Munic.	. . . .	. .	. .[5]	. .
Gardner, Greenwood Memorial	75	30	7.5	3	90 000	Munic.	2.4	8	8–1 140	79
Gloucester, Y. M. C. A.	28	20	7	4.5	24 000	Munic.	12	5	100–250	137
Haverhill Y. M. C. A.	38	19	7	4	29 700	Munic.	6	9[1]	500	59
Lawrence Y. M. C. A.	60	20	7	3	46 000	Munic.	1	4 to 8	500	92
Lowell Y. M. C. A.	60	22	9	4	65 000	Canal	13	10	. . .	. .
Lynn Y. M. C. A.	40	20	8	4	33 000	Well	4	10	450	73
Malden Y. M. C. A.	60	20	7.5	3.5	55 000	Munic.	4	10	400–500	122
Melrose Y. M. C. A.	40	20	7	3	33 000	Munic.	1	20[2]	300	110
New Bedford Y. M. C. A.	40	20	7	4	35 000	Munic.	2–2.4	17	250	140
Newton Y. M. C. A.	60	21	6.5	3	50 000	Munic.	0.33	12	500–600	91
Norwood Civic Association	60	20	8.5	4	60 000	Munic.	. . . .	14	350	171
Quincy Y. M. C. A.	32	18	6	4	21 550	Munic.	4 or more	6	50	430

Phillips Academy, Andover	75	30	8.5	4	88 000	Munic.	3	10	600	147
Phillips Academy, Exeter, N. H.	75	26	8.87	3.87	97 000	Wells			..[5]	
Radcliffe College, Cambridge	60	20	7	4.5	50 000	Munic.	91		164	305
Somerville Y. M. C. A.	35.67	19.17	6	3.5	32 560	Munic.	2	5-6	300-400	93
Springfield Y. M. C. A.	75	25	7	3.5	75 000	Munic.	17	24	900	83
Taunton Y. M. C. A.	40	25	6.5	3	26 200	Munic.		8+	260	105
Waltham Fellowship House	66	25	6.25	3.5	55 000	Munic.	26-52	3+	S600-800	79
Worcester Academy	75	30	10	5	120 000	Munic.	1	4	300	400
Worcester Boys' Club	60	20	7.5	3	45 000	Munic.	104	12-15	500	90
Worcester Y. M. C. A.	100	25	8	4	130 000	Sp. water	2	14	..[5]	
Y. M. C. A. College, Springfield	60	24	8	4	75 000	Well	1-2	10	1 500	50

S — Summer. [1] Every two days. [2] Per week. [3] Operated seven days per week. [4] For games and contests, larger figure can be made available. [5] Pool not placed in use up to time of reporting. [6] About 4 ft. of water added per day.

TABLE 5. — DATA RELATING TO OPERATION OF SWIMMING POOLS.

Location.	Rate of Circulation Pump. (Gals. per Min.)	Coagulant.		Alkali.		Disinfectant.		Temperature of Water, Degrees F.
		Kind.	Pounds per Week. (6 days.)	Kind.	Pounds per Week. (6 days.)	Kind.	Pounds per Week. (6 days.)	
Amherst College, Amherst	150	Alum	2.5	Soda ash	2.5[2]	Chloride of lime	$1\frac{7}{8}$	75
Beverly Y. M. C. A.	....	Alum	....	....	..	Copper sulphate	$1\frac{1}{8}$	76–78
Boston Athletic Association	...	....	....	....	..	Chloride of lime	1	70
City of Boston—Curtis Hall	....	Alum	4	Soda ash	4	None	....	70–74
City of Boston—Columbia Road[3]	None	None	...	None		Chloride of lime	3	70–74
City of Boston—Cabot Street[3]	None	None	..	None		Chloride of lime	3	70–74
Boston Y. M. C. A.	....	Alum	..	....		Copper sulphate	0.3	72
Brookline Municipial	125	Alum	2	....		Chloride of lime	12	75–78
Cambridge Y. M. C. A.	50	None	....	None		Copper sulphate	4.8	70
Dean Academy, Franklin	....	....	....	Soda ash		Chloride of lime	....	65
Framingham Civic League	....	Alum	....	Soda ash		Chloride of lime	....	....
Gardner, Greenwood Memorial	150	Alum	0.75	....	...	Chloride of lime Copper sulphate	2.25 0.3	74–75
Gloucester Y. M. C. A.	....	Alum	3	Soda ash	7	Chloride of lime	3	71
Haverhill Y. M. C. A.	....	Alum	3+	Soda ash	3+	Chloride of lime	0.25	67–72
Lawrence Y. M. C. A.	65	Alum	....	Soda ash	...	Chloride of lime	3	....
Lowell Y. M. C. A.	100	....	....	Soda ash	5	Chloride of lime	0.25+	....
Lynn Y. M. C. A.	....	Alum	0.25	Soda ash	0.25	None	.... —	65–70
Malden Y. M. C. A.	83	Alum	10	Soda ash	1.25	Chloride of lime	5	72
Melrose Y. M. C. A.	....	Alum	....	....	....	Chloride of lime	1	65
New Bedford Y. M. C. A.	30	Alum	3	Soda ash	0.25	None	....	76
Newton Y. M. C. A.	..	Alum	1	....	....	Chloride of lime	3	74
Norwood Civic Association	....	Alum	3	Soda ash	1.5	Chloride of lime Copper sulphate	0.25	73–74

Quincy Y. M. C. A.	....	Alum	....	None		Chloride of lime	0.75	70
Phillips Academy, Andover......	110	Alum	7.5	Soda ash	10	Chloride of lime	6	70
Phillips Academy, Exeter, N. H..	....	....	....	....		Chloride of lime	....	
Radcliffe College, Cambridge....	83	None	....	Soda ash	5	Chloride of lime	3	72
Somerville Y. M. C. A.		Alum	0.25 to 0.5	Soda ash	1	Chloride of lime	0.19	70
Springfield Y. M. C. A..	100	Alum	13			Ultra violet rays		74
Taunton Y. M. C. A..........		Alum				Chloride of lime	0.25	70 72
Waltham Fellowship House		Alum				Chloride of lime	2.25 to 3	66 74
Worcester Academy		Alum	1			{Chloride of lime {Copper sulphate	3 3	70 76
Worcester Boys' Club	100	Alum	4			Chloride of lime	3.5	74
Worcester Y. M. C. A.	150	Alum		Soda ash		Liquid chlorine		68 75
Y. M. C. A. College, Springfield..	130	Alum	6	Soda ash		{Copper sulphate {Chloride of lime	3	76 80

[1] One-quarter lb. per 1 000 gals. 3 times per week. [2] When necessary. [3] Operated 7 days per week.

was of advantage in keeping the water in good condition, but others found direct sunlight caused increased growths of algæ, and consequently was a source of further trouble. This latter would be especially true where ground water is used as a supply.

At all times the pool and room should be well lighted, thus increasing the attractiveness of the pool and making it all the more necessary to maintain sanitary conditions. Electric lights can be used at night, with good effect.

Operation.

Source of Water Supply. — It is interesting to note that five out of the thirty-four pools obtain their water from driven wells, and one uses spring water obtained on the property. All but one of the others use the municipal supply. The water for the Boston Y. M. C. A. pool is taken from two artesian wells over 400 ft. deep, and is salt.

Refilling Pool. — The period between times of emptying the pools and refilling completely, varies greatly. In nearly all of the pools a certain amount of fresh water is added daily, or every few days, to replace that lost by splashing or overflow, or washing filters, or drawing out sediment. In this manner the water may be said to be replaced once in three months, perhaps. Many of the large and well-operated pools are emptied but once in from five to twelve months, or even longer. The Cambridge Y. M. C. A. pool has not been emptied for about fourteen months, but the water is maintained in satisfactory condition by scientific treatment, as is indicated in the discussion by Mr. M. C. Whipple. The period during which satisfactory conditions can be maintained may depend to a large degree upon the extent to which algæ grows, although trouble from this source can be materially reduced by dosing with copper sulphate and by using a vacuum cleaner or suction brush.

By refilling only at infrequent intervals and provided, of course, that the quality of the water is maintained by treatment, substantial savings in water and heat are made, the color of the water is kept at a satisfactory point, and a uniformly low bacterial content can be assured. The water, supplied in the Metropolitan District, has sufficient color to be dark and unattractive

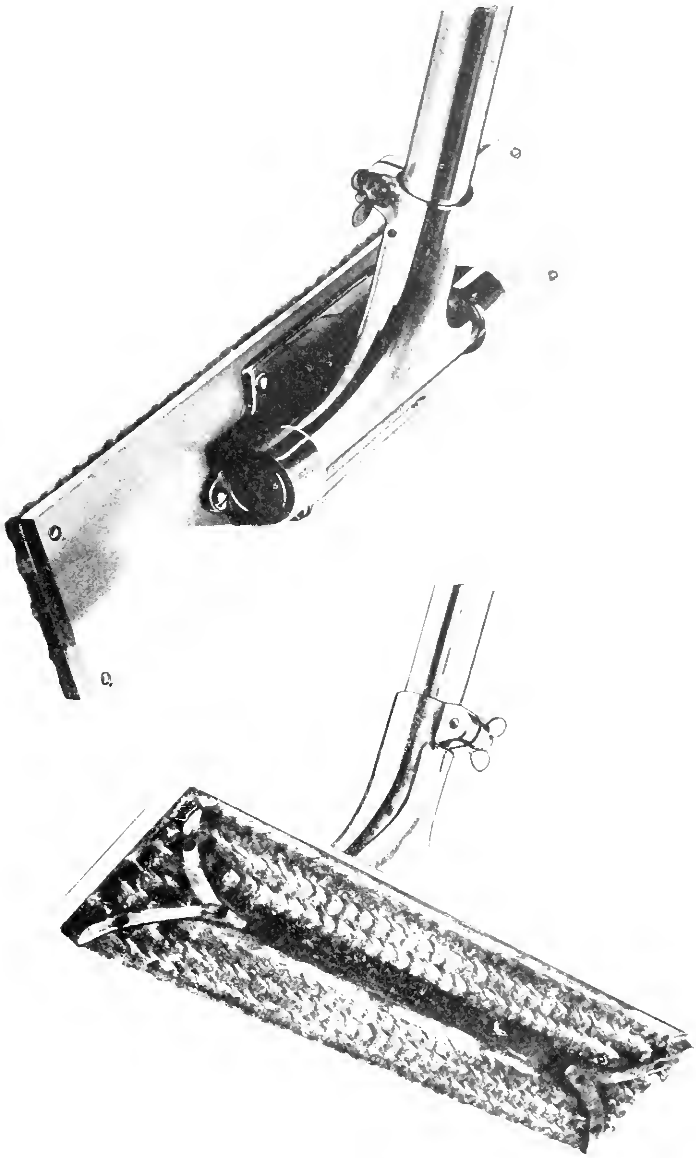

FIG. 22. SUCTION BRUSH.

when collected in a large white pool, although it is entirely satisfactory for a drinking water. After a few days in the pool, however, with proper treatment, the color can be reduced to a satisfactory degree, but where the pool is emptied every few days the color is liable to be uninviting the most of the time.

Removing Sediment. — The best method reported for removing sediment from the bottom of the pool is by means of a

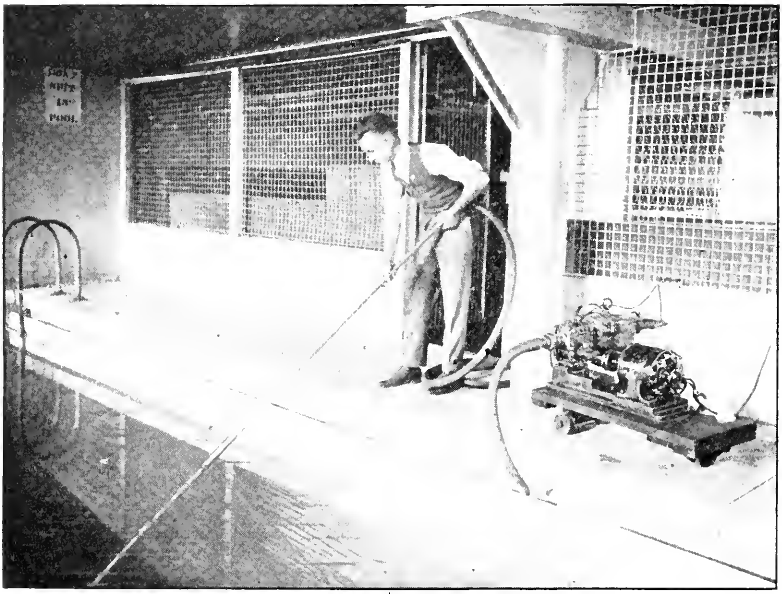

FIG. 23. CLEANING QUINCY Y. M. C. A. NATATORIUM.

long-handled suction brush, somewhat similar to brushes used with vacuum cleaners. A brush of this type is shown in Fig. 22, the cut for which was loaned by the Sanitary Dust Removing Company, of Boston. The brush has short, stout bristles and is operated by a hollow handle through which water is drawn (when immersed) by a suction pump either stationary or portable. It is reported that centrifugal pumps have not given satisfaction for this service. Fig. 23 shows a brush of the above type, in use at the Quincy Y. M. C. A. It is connected to a

little portable pumping outfit made up of a Kinney bronze rotary pump, size SD373, driven by a direct-connected $1\frac{1}{2}$ horse-power Century motor, furnished by The Kinney Manufacturing Company of Boston. The pump discharge is through a flexible hose into the spit trough. The suction pipe is provided with a strainer and may have a check valve near the brush to maintain the priming of the pump while going from one side of the pool to the other. In general, the pump should have a capacity of about 50 gals. per minute when operating against a 10-ft. head (largely suction lift). The water may be discharged into the filters or wasted into the sewer. The latter method is generally used.

Filters. — All of the pools (excepting the Columbia Road and Cabot Street pools of the city of Boston) are equipped with mechanical filters for purifying the water. The majority are of the pressure or enclosed type. In either case, whether of the gravity or open type or the pressure or enclosed type, the sand is washed by pumping water through the filter in the reverse direction into the drain or sewer, to carry off the dirt accumulated in the sand. It appears evident that the water must be changed continuously or else circulated through a filter, in order to maintain an acceptable standard of purity. The former method is usually too expensive to be adopted. The circulation pumps should be operated at such a rate and for a sufficient period, especially during the hours of use, so that the entire contents of the pool may be filtered at least once a day. Needless to say, the filters should be of ample capacity to handle this rate of filtration.

In general, alum (aluminum sulphate) is used as a coagulant, to assist the filters, being applied either directly to the water in the pool, or by a feed device to the water in the pipe line entering the filters.

Alum requires a certain amount of alkalinity in the water for its proper action. The continual use of the same water by filtration, even though a small amount of fresh water be added daily, reduces the natural alkalinity to such an extent that with soft waters, additions must be made to the alkalinity from time to time, in order to prevent undecomposed alum from causing

complaints. Seventeen of the pools reported the use of soda ash to maintain the alkalinity of the water.

The quantities of alum reported are listed in Table 2. In the case of the Y. M. C. A. College at Springfield, the pump operates at a rate of 130 gals. per minute for approximately ten hours per day, thus filtering about 78 000 gals. (the pool has a capacity of 75 000 gals.) Using 1 lb. of alum per day is equivalent to 12.8 lbs. per million gallons of water filtered, or about 0.09 grain per gallon, or 1.54 parts per million.

Disinfectants. — By far the most common disinfectant used is chloride of lime. Out of 34 pools reporting, 26 use this chemical, 4 of these pools using copper sulphate also, 3 others use copper sulphate only; 1 reported using ultra-violet rays (Springfield Y. M. C. A.); 1 uses liquid chlorine (Worcester Y. M. C. A.) and 3 use none of these agents, depending on filtration and the use of alum and soda ash.

The replies indicate that copper sulphate is recognized as of particular value in reducing growths of algæ, and by some is preferred for general use in the pool as a germicide.

Chloride of lime when fresh and properly handled has proven of great value. It deteriorates upon exposure to the air, and for that reason its use may lead to a false sense of security unless regular bacterial analyses of the water are made.

A common method adopted for applying the chloride of lime is to scatter the dry powder over the surface of the water. This is objectionable for the following reasons: The dry powder is objectionable to the caretaker who handles it in this manner; the odor permeates the room in an unpleasant way; fine particles float on the surface causing unsightly patches, or the larger particles sink to the bottom increasing the deposit of sediment; and the value of the chemical as a sterilizing agent may be reduced by the decomposing action of the air.

Professor Bonnet has suggested the use of a solution of 1 lb. of chloride of lime to 5 gals. of water. This mixture should be stirred for a few minutes, then allowed to settle, thereby getting rid of the insoluble portion. The solution can be distributed over the surface of the water in the pool by means of an ordinary watering-can with a long spout. Professor Bonnet

further suggests the application of chloride of lime in a similar manner to the method frequently adopted in using copper sulphate. That is, to use a salt or cheese-cloth bag in which the powdered chemical is placed, the bag being fastened to a pole or weighted and attached to lines, thus permitting it to be drawn back and forth through the water all about the pool. In this way the objections previously raised may be overcome.

Where special apparatus is provided, as is preferable, for applying the disinfectant to the water as it leaves the filters, the above methods are unnecessary.

In recent years, apparatus has been developed for applying liquid chlorine to water, and is now extensively used for the disinfection of public water supplies. In the case of swimming pools, the first cost of the liquid chlorine apparatus is a large item. For general use, however, by unskilled operators, or where scientific supervision is lacking, chloride of lime is probably safer and more satisfactory. The use of the ultra-violet rays prevents the objection made by some to the use of any kind of chemical treatment. For such use it has been claimed, in some instances, to be more economical to operate than the older method of using chloride of lime.

Temperature of Water. — The temperature at which the water is maintained varies from 65 degrees to 78 degrees Fahr., the average being about 72 degrees. As a rule, the room is kept several degrees warmer than the water.

Methods of Heating Water. — Three methods of heating the water as it circulates from the pool and through the filters, are in general use. A steam-jacketed water tank or steam jacket around the supply pipe is the most common method, using either live or exhaust steam. A second method is to use a feed water heater such as are used in power plants for heating boiler feed water with exhaust steam. The third method is by the injection of live steam into the water-supply pipe.

Gas heaters of the instantaneous type are sometimes used either for an emergency, as at the Norwood Civic Association, or for regularly heating the water. For regular use under usual conditions they are apt to prove expensive to operate.

The temperature may be controlled by hand regulation of

the steam valve or preferably by a thermostatic valve working automatically.

Bathing Load. — Several writers have adopted standards for the comparison of the burden placed upon swimming pools. Such a standard may be obtained by dividing the capacity of the pool, in gallons, by the average total number of bathers per week. This standard has been computed as far as possible with the data available for the pools listed in the table. For a number of the pools, the capacity was not given, but has been estimated from the data available.

Rules Concerning Bathers. — Nude bathing is required at many of the pools for men and boys. Where suits are allowed, they are generally furnished by the management or else required to be uniform in style and of fast color and free from lint. The best practice seems to require that suits, when allowed, should be thoroughly washed and sterilized after using, by equipment maintained by the pool management.

At all of the Y. M. C. A. pools and at many of the other non-public pools, physical examinations of the bathers are made from time to time, and in addition, all bathing is done under inspection.

All pools reported requiring a hot shower bath with soap before entering the pool. This rule can be more readily enforced where the shower baths are adjacent to the pool, and especially so where it is necessary to pass through the shower bathroom in order to reach the pool. The importance of the strict enforcement of the bathing rule cannot be exaggerated. That the enforcement of this rule should be a continual source of complaint, even when dealing with well-educated persons of mature age, is surprising, but from all reports appears to be a fact, nevertheless.

Precautions against Accident. — The replies received in regard to this subject indicate that under no conditions should swimming alone in a pool be permitted. It is the practice at most pools to have at least one instructor present, and usually at least three persons. Life preservers should be placed within easy reach and at some pools a call bell is provided to make it possible to summon assistance in case of accident. A pulmotor

is considered by some as a necessary part of the equipment. Where steam pipes or radiators are located in the pool or room about the pool, they should be fully protected by guards to prevent bathers being burned. Steps or ladders and handrails should be conveniently located.

The results of this investigation have impressed the writer with the great need of expert inspection and control of swimming pools by some central authority, provided with enforcement powers to make it possible to keep the water of the pools in reasonably good sanitary condition. Studies made at a number of pools have shown how easily the water may be prevented from becoming seriously polluted and a possible source of infection, by proper supervision aided by chemical and bacteriological analyses. Many pool operators are not provided with funds for obtaining such aid. It would seem that the use of swimming pools is becoming so widespread as to call for the protection of the persons using them by providing the required supervision, from public funds. The action of the Rhode Island authorities, as outlined by Mr. Gage, is therefore particularly commendable. It is further believed that an inspection of the small pools or "plunges" in Turkish-bath establishments and clubs would reveal the need of better supervision of the treatment of the water.

MR. GAGE.* — The matter of ultra-violet rays has been mentioned. When using the ultra-violet rays, a small amount of water is carried through the apparatus, sterilized, and mixed with the water in the pool, and the question of the purification is not a simple question of the amount of the bacterial removal by the disinfecting apparatus but a question of the dilution. As I tried to make clear on the diagram, with the usual circulation system it takes four to ten days to obtain purification by dilution and this would also hold true in the case of the violet ray apparatus. With chlorination by hypochlorite, on the other hand, the disinfectant is added directly to the pool and the whole body of water disinfected at one time. With chlorination by chlorine gas, a condition similar to that with the ultra-violet rays, is obtained. That is, a small portion of the water is steril-

* Author's Closure.

ized and returned to the pool and the purification is therefore a question of dilution.

There has been quite a little data published to show that this process is effective in destroying bacteria in clear waters, but so far as I know not much has been published as to its use in connection with swimming pools. My criticism was based upon theoretical grounds as I have had no personal experience with violet ray disinfection.

Mr. Percy M. Blake has enquired as to the relative advantages of a stored surface water and a ground water and also as to the amount of chemical treatment which might be required under the two conditions.

A stored surface water would probably run much higher in color than a well water, and when the pool was first filled it would take somewhat longer to get it cleaned up,—that is to get the color of the water down where the pool would appear attractive. Further than that, I do not see that there would be any material advantage in one water over the other. There should not be any physiological difference to the bathers or any appreciable difference in the load on the purification system except in that initial period. Mr. Weston suggests there might possibly be iron in the ground water, and in that case it would be rusty or colored and would have to be filtered to give it a satisfactory appearance, the same as would have to be done with a surface water. Rusty water is one of the serious troubles in refilling a pool from city mains, owing to the rust stirred up in the pipes by the increased velocity of the water. For example, at Newport the city water is so low in color that it could be used for filling the swimming pools without filtration if it was not for the rust that is stirred up when filling.

So far as I can see the hardness of the ground water would not appreciably affect any of the treatments ordinarily applied to swimming-pool waters. As the pool is continued in use, especially if hypochlorite of lime is used as a disinfectant, there will always be a gradual increase in the hardness of the water. The relative increase would be about the same whether you start with a soft surface water or a hard ground water. Unless the pool were continued in use without refilling much longer than is

the usual practice, I do not believe this would ever become objectionable.

Bathing in ponds used as sources of water supply has also been brought up. Two or three years ago, we found that a lake used as a source of drinking water for one of our state institutions was being used for bathing. The bathing beach was over a mile from the water-works intake and the number of bathers was small, but we felt that bathing in a pond used as a drinking-water supply was potentially dangerous, and stopped it.

The question of the sanitary aspect is a question of reasonable danger, and we as health officials had to consider that there was a possibiliy of contamination from persons bathing. We know that persons bathing in fresh or salt water in the open are not always as cleanly as they might be, and sometimes use the water for purposes for which it should not be used, and we felt that contamination from this source might be carried by winds and currents across the lake to the water supply. It was a water-supply question, and we had to be on the safe side. As to what degree of pollution might be safe or dangerous to persons bathing I cannot answer the question. As I said, we started to make a study of the outdoor bathing beaches and of the wading pools for children which are to be found in our cities but so far this study has not gone far enough for me to draw any conclusions.

The whole question of bacterial standards which has been mentioned is rather up in the air, even on what limits shall be placed on the bacterial content of water for drinking purposes. I have been accustomed to assume that if a bathing pool is as good bacterially as a good drinking-water supply the bathing pool was entirely safe. This may be setting the standard rather high for bathing water; but we are on the safe side.

The United States public health standard for drinking waters to be used on trains in interstate service requires that B. coli shall not be found in more than " one out of five 10 cc. portions of any sample of the water." A good many think this standard is somewhat stringent, but it is a very good one to apply because it has the backing of the United States Government.

The standard also limits the numbers of bacteria to 100

per cc. In swimming-pool work, however, I have not been accustomed to pay much attention to the total bacteria because we are bothered by aftergrowths. During disinfection we destroy the great majority of the bacteria, probably all of certain kinds, and thus upset the natural bacterial balance of the water. As a result, conditions are favorable for the few remaining bacteria, or for bacteria introduced by bathers, to multiply rapidly, giving us very high counts. So you might have a million bacteria and at the same time the types of bacteria on which we are accustomed to figure your pollution, — might be entirely absent. Under these conditions we would have to ignore the high counts and base our interpretation on other evidence.

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J. Munic. Eng., Vol. 49 (1915), p. 212.
Swimming Pool and Flush Tank Combined at Oakdale, Cal. Dimensions and cost of open concr. pool out-of-doors, built in form of tank; waste water used to flush sewers.

Brickb., Vol. 24 (1915), pp. 13–16, and plates following.
Edit. on public bathing establishments; photographs, plans and details of various pools in American cities.

Brickb., Vol. 24 (1915), pp. 101–102.
South side bathhouse, Pittsburgh, Pa. — views and plans.

Metal Wk., Vol. 84 (1915), pp. 522–523.
Swimming Pool at Pittsburgh Athletic Club.

Metal Wk., Vol. 83 (1915), pp. 796–798.
Wealthy Californian's Pool de Luxe.

Metal Wk., Vol. 84 (1915), pp. 729–730; pp. 837–838.
Plumbing and Heating Details of Plunges.

Metal Wk., Vol. 84 (1915), pp. 605–607.
Plumbing Work in Harvard Club of New York.

Metal Wk., Vol. 83 (1915), pp. 288–290, and *Building Age*, Vol. 37, pp. 39–40.
Plumbing Equipment of Swimming Pool, Louisville, Ky.

Metal Wk., Vol. 83 (1915), p. 727.
St. Louis Builds Large Swimming Pool.

Dom. Eng., Vol. 73 (1915), pp. 134–137.
Natatorium in the Evander Childs' High School, N. Y. City, by E. R. Porter.

Dom. Eng., Vol. 72 (1915), p. 229.
Concrete Natatorium for Chicago School Children.

Build. Age, Vol. 37 (1915), pp. 51–52.
Details of Open-Air Swimming Pool.

Arch. Rec., Vol. 37 (1915), pp. 116–131.
Jn. C. Proctor Recreation Center, Peoria, Ill.; photographs, plans and brief description.

Arch. Rec., Vol. 38 (1915), pp. 171–176.
Swimming Pool at Home of Miss Helen Gould, Irvington, N. Y.; photographs, plans and detailed plates giving dimensions. No text.

Eng. News. Vol. 74 (1915), p. 821.
Municipal Swimming Pool, Grand Rapids, Wis. Brief article; pool situated below dam; fed by continuously running stream; concrete walls, sand bottom, sluice gate.

Conc.-Cem. Age, Vol. 6 (1915), pp. 148–149.
Swimming Pool at Rockledge, Fla.; construction and design; gives details and photographs.

Dom. Eng., Vol. 74 (1916), pp. 391–393.
Information about swimming pools.

Metal Wk., Vol. 85 (1916), pp. 188–189; pp. 350–351; pp. 633–635.
Plumbing and Heating Details of Plunges.

Metal Wk., Vol. 85 (1916), pp. 33–36.
Pullman, Ill., Municipal Swimming Pool — has unique features.

Heat. & Vent., Vol. 13 (1916), pp. 39–40.
Data for figuring an indoor plunge.

Dom. Eng., Vol. 77 (1916), pp. 36–37.
Heating and Plumbing System in a Public Natatorium in Chicago.

Concr., Vol. 8 (1916), pp. 149–150.
Construction of Concrete Swimming Pool at Pendleton, Ore., by L. R. W. Allison. Describes pool; table of construction costs and method of financing.

El. R. & W. Elec., Vol. 68 (1916), p. 464.
Quarter Horse-power Motor Saver of $25 per Month for Swimming Pool.

Dom. Eng., Vol. 77 (1916), p. 289.
Plumbing and heating of new swimming pool at Union League, Club Chicago.

Eng. & Contr., Vol. 44 (1917), p. 357.
Design features of reinf. concrete swimming pool at Riverview Park, Chicago; gives plan and section and table of reinforcement used.

J. West. Soc. C. E., Vol. 22 (1917), pp. 16–35.
Addition to the Union League Club (Chicago), by Fk. E. Brown. Describes construction and gives detailed drawings of pool. (See also *Eng. News*, Vol. 77 (1917), pp. 56–57.

Eng. Rec. (1917), pp. 106–107.
Construction of Swimming Tank in Union League Club, Chicago,—description, plan; details of piers; steel plate construc., lead-lined, membrane waterproofing, ceramic tile.

Dom. Eng., Vol. 80 (1917), pp. 365.
Modern Outdoor Swimming Pools, by J. A. Ward.

Dom. Eng., Vol. 79 (1917), pp. 366–367.
Swimming Pools in Public Schools.

Metal Wk., Vol.. 87 (1917), pp. 701–703.
Swimming Pool heating and filtering plant.

Dom. Eng., Vol. 79 (1917), pp. 47–48.
Roof Swimming Pools Offer Opportunity for More Bathers in Congested Communities.

Elec. W., Vol. 69 (1917), p. 470.
Lighting swimming pool with submerged lamps. Pool at Seattle, Wash. Brief article, with cross-section of lighting unit.

Concr., Vol. 10 (1917), pp. 181–183.
Design of Pools Built of Concrete. Protection against frost, proper foundation; water-tightness; three illustrations of pool; design of typical pool.

Harding & Willard—Mechanical Equipment of Buildings 1916, 1st Ed., Vol. I, p. 181.
Methods of heating water; steam and boiler horse-power required; area of steam coils and connections necessary.

Abbreviation.	Title.
Amer. City	American City.
Am. J. Pub. Hyg.	American Journal of Public Hygiene.
Am. Phys. Ed. Rev.	American Physical Educational Review.
Am. Med.	American Medicine.
Arch. Rec.	Architectural Record.
Arch. Rev.	Architectural Review.
Assn. Mun. & Cty. Eng.	Association of Municipal and County Engineers.
Boston Med. J.	Boston Medical Journal.
Brickb.	Brickbuilder.
Build. Age	Building Age.
Concr.	Concrete.
Conc.-Cem. Age	Concrete-Cement Age.
Dom. Eng.	Domestic Engineering.
El. R. & W. Elec.	Electrical Review and Western Electrician.
Elec. W.	Electrical World.
Eng. & Contr.	Engineering and Contracting.
Eng. News	Engineering News.
Eng. Rec.	Engineering Record.
Gsndhts. Ing.	Gesundheits Ingenieur.
Heat. & Vent.	Heating and Ventilating Magazine.
House & Gard.	House and Garden.
Hyg. Runds.	Hygienische Rundschau.
J. Am. Med. Assoc.	Journal of the American Medical Association.
J. Am. Pub. Health	Journal of the American Public Health Association.
Jour. Am. W. W.	Journal of the American Water Works Association.
J. Ind. & Eng. Chem.	Journal of Industrial and Engineering Chemistry.
J. Infec. Diseases	Journal of Infectious Diseases.
J. West. Soc. C. E.	Journal of the Western Society of Civil Engineers.

Abbreviation.	Title.
Mass. St. Bd. Health	Massachusetts State Board of Health.
Metal Wk.	Metal Worker, Plumber and Steam Fitter.
Munic. Eng.	Municipal Engineering.
Munic. J. & Eng.	Municipal Journal and Engineer.
Ohio Pub. H. Jour.	Ohio Public Health Journal.
Philip. Bur. Sci.	Philippine Bureau of Science.
Phys. Training	Physical Training, published by Physical Directors' Society of the Young Men's Christian Associations of North America.
Power	Power.
Proc. Am. Assn. Prom. Hyg. & Pub. Baths	Proceedings of the American Association for the Promotion of Hygiene and Public Baths.
Proc. Ill. Wa. Sup. Assn.	Proceedings of the Illinois Water Supply Association.
Proc. Ind. San. Wa. Sup. Assn.	Proceedings of the Indiana Sanitary and Water Supply Association.
Proc. N. E. Assoc. Chem. Teachers	Proceedings of the New England Association of Chemistry Teachers.
Rept. Med. Officer Loc. Gov. Bd., Eng.	Report of the Medical Officer of the Local Government Board, England.
Sci. Am.	Scientific American.
Sci. Am. S.	Scientific American Supplement.
Surv.	Survey.
Thomp. Yates Lab. Repts.	Thompson Yates Laboratory Reports.
U. S. Pub H. Repts.	U. S. Public Health Reports.

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PAPERS AND DISCUSSIONS

DISCUSSION OF ECONOMY IN THE DESIGN OF CONCRETE BUILDINGS.

By Frank S. Bailey, J. R. Worcester, Leslie H. Allen, Burtis S. Brown, John R. Nichols.

Frank S. Bailey.* — The writer has been considerably interested in Mr. Mayer's paper. In computing the unit costs of concrete of 1 : 1½ : 3 and 1 : 1 : 2 mixes, Mr. Mayer uses the same amount of aggregate as he did in figuring the cost of the 1 : 2 : 4 mix and simply adds the cost of the increased quantity of cement. This is a common custom. It may be of interest to know what the difference is in the cost of the different mixes, if allowance is made for the diminished amounts of aggregate in the richer mixes. Computations of the cost of different mixes, using Mr. Mayer's unit prices, and taking the quantities of cement, sand and gravel from Taylor and Thompson's "Concrete Costs," page 151, for average conditions, give results shown in Table 1.

It is of interest to note that the cost of the 1 : 2 : 4 and 1 : 1½ : 3 mixes is about 5 per cent. more by the customary method than by Taylor & Thompson's figures, and about 9 per cent. more for the 1 : 1 : 2 mix; the usual method being slightly unfavorable to the richer mix.

It may be suggested that in designing columns it is well to follow the rule of trying first a concrete mix of 1 : 1 : 2 with 1

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TABLE 1.

		Cost of Concrete per Cu. Ft. T. & T. tables.	Cost of Concrete per Cu. Ft. Mayer.	Per Cent. Increase of Mayer's.
1 : 2 : 4 mix.				
1.57 bbl. cement at $2	$3.14			
.44 cu. yd. sand at $1.50	.66			
* 1 205 tons broken stone at $2	2.41			
Plant, mixing and placing	2.50			
Total cost per cu. yd.	$8.71	$0.323	.34	5.3
1 : 1½ : 3 mix.				
2.00 bbl. cement at $2	$4.00			
.42 cu. yd. sand at $1.50	.63			
* 1 135 tons broken stone at $2	2.27			
Plant, mixing and placing	2.50			
Total cost per cu. yd.	$9.40	.348	.365	4.9
1 : 1 : 2 mix.				
2.73 bbls. cement at $2	$5.46			
.38 cu. yd. sand at $1.50	.57			
* 1.04 tons broken stone at $2	2.08			
Plant, mixing and placing	2.50			
Total cost per cu. yd.	$10.61	.393	.43	9.4

* 20 cu. ft. = 1 ton.

per cent. of vertical steel, in square or rectangular columns, and the same mix and ratio of vertical steel with 1 per cent. of steel spirals for round columns; then, if the right ratio of length to diameter of column is not exceeded, and there are no bending moments to be considered, comparisons with other mixes or steel ratios are needless, as none will show greater economy. It is well known that it is more economical to use a low ratio of steel for compression where saving in space is not a factor, and Mayer's figures show that this fact holds true when ordinary values are allowed for space saved by using more steel. Table 2 shows the relative economy of the three mixes in columns without spiral hooping.

TABLE 2.

SHOWING COMPARATIVE COSTS PER 100 000 LBS. COMPRESSIVE STRENGTH OF DIFFERENT MIXES OF HARD SANDSTONE CONCRETE, USING JOINT COMMITTEE'S VALUES FOR COMPRESSION AND MAYER'S COST FIGURES.

Mix.	Compressive Strength. Lbs. per Sq. In.	Lbs. per Sq. Ft.	Cost per Cu. Ft.	Cost per 100 000 Lbs. Compressive Strength.
1 : 2 : 4	450	64 900	\$0.34	\$0.525
1 : 1½ : 3	563	81 000	0.365	0.450
1 : 1 : 2	675	97 200	0.43	0.442

NOTE. Where large bending moments exist in columns, the conditions of stress are analogous to those in a beam, and it is possible that in some cases a 1 : 2 : 4 mix will compare favorably as to cost with the 1 : 1 : 2.

The same relative economy for the 1 : 1 : 2 mix at prices prevailing ten years ago is shown in the following tables, in which the cost figures are taken from a paper by Mr. L. C. Wason, member of Boston Society of Civil Engineers, on "Proportioning and Mixing Cement Mortars in Concrete," which was printed in the Proceedings of the National Association of Cement Users for 1908.

TABLE 3.

SHOWING COMPARATIVE COSTS PER 100 000 LBS. COMPRESSIVE STRENGTH OF BROKEN STONE CONCRETE.

(Based on prices for the year 1908.)

Concrete Mix.	Compressive Stress (Joint Committee Values for Hard Limestone). Lbs. per Sq. In.	Lbs. per Sq. Ft.	Cost per Cu. Ft. of Concrete.	Comparative Cost per 100 000 lbs. of Compressive Strength.
1 : 2 :4	450	64 900	\$0.264	\$.408
1 : 1½ : 3	562.5	81.000	.283	.350
1 : 1 : 2	675	97 200	.314	.323

TABLE 4.

SHOWING COMPARATIVE COSTS PER 100 000 LBS. COMPRESSIVE STRENGTH OF GRAVEL CONCRETE.

1 : 2 : 4	450	64 900	\$0.214	\$0.330
1 : 1½ : 3	562.5	81 000	.237	.293
1 : 1 : 2	675	97 200	.274	.282

Costs in Tables 3 and 4 based on following constants:

Cement delivered on job, per barrel, net	$1.75
Broken stone (21 cu. ft. = 1 ton) per ton	1.50
Sand, per cu. yd.	1.20
Gravel (containing stone and sand in right prop.) per cu. yd.	1.15
Labor (foreman, common and miscellaneous), $0.06 per cu. ft. or per cu. yd.	1.62

It is therefore apparent that the 1:1:2 mix is the most economical of the three for furnishing uniform compressive strength in columns; and, if the cost figures of Table 1 are used, there is shown a still greater relative economy for this mix. It is also evident that the 1 : 1 : 2 mix is the more economical to use for compressive strength in columns with spiral hooping, as the ratio of increases in allowable stress is the same for each mix, and there is a slight advantage for the richer mix from the fact that a smaller section can be used, thus requiring less spiral steel.

The following tables have been prepared to show the approximate relative costs of beams or slabs of various concrete mixes, when the bending moment is the controlling factor in determining the section.

TABLE 5.

SHOWING APPROXIMATE COST PER LINEAR FOOT OF BEAM OR SLAB OF DIFFERENT MIXES OF CONCRETE, WITH STRESS IN STEEL 16 000 LBS. PER SQ. IN.

Mix.	Cost of Concrete per Lin. Ft. of Beam.	Cost of Steel per Lin. Ft. of Beam.	Total Cost per Lin. Ft. of Beam.
1 : 1 : 2	$\$0.000236\sqrt{Mb}$	$\$0.000154\sqrt{Mb}$	$\$0.000390\sqrt{Mb}$
1 : $1\frac{1}{2}$: 3	$0.000218\sqrt{Mb}$	$0.000140\sqrt{Mb}$	$0.000358\sqrt{Mb}$
1 : 2 : 4	$0.000226\sqrt{Mb}$	$0.000125\sqrt{Mb}$	$0.000351\sqrt{Mb}$
1 : $2\frac{1}{2}$: 5	$0.000256\sqrt{Mb}$	$0.000103\sqrt{Mb}$	$0.000359\sqrt{Mb}$

TABLE 6.

SHOWING APPROXIMATE COST PER LINEAR FOOT OF BEAM OR SLAB OF DIFFERENT MIXES OF CONCRETE, WITH STRESS IN STEEL 18 000 LBS. PER SQ. IN.

Mix.	Cost of Concrete per Lin. Ft. of Beam.	Cost of Steel per Lin. Ft. of Beam.	Total Cost per Lin. Ft. of Beam.
1 : 1 : 2	$\$0.000242\sqrt{Mb}$	$\$0.000131\sqrt{Mb}$	$\$0.000373\sqrt{Mb}$
1 : $1\frac{1}{2}$: 3	$0.000226\sqrt{Mb}$	$0.000120\sqrt{Mb}$	$0.000346\sqrt{Mb}$
1 : 2 : 4	$0.000234\sqrt{Mb}$	$0.000106\sqrt{Mb}$	$0.000340\sqrt{Mb}$
1 : $2\frac{1}{2}$: 5	$0.000265\sqrt{Mb}$	$0.000089\sqrt{Mb}$	$0.000354\sqrt{Mb}$

Tables 5 and 6 were computed by the following method.

For a given quality of concrete and steel in a beam or slab the depth to the steel may be expressed by the formula $d = C\sqrt{\frac{M}{b}}$,

in which M = Bending moment in inch lbs.

b = Breadth of beam or slab in inches.

C = A constant (for a given combination of concrete and steel).

Values of C for different stresses in concrete and steel are given on page 483 of the third edition of "Concrete, Plain and Reinforced," by Taylor and Thompson. Concrete stresses for different mixes are those recommended by the Joint Committee for concrete with hard sandstone aggregate, and costs are Mr. Mayer's figures.

To illustrate, take the 1:1:2 mix in Table 5; $d = 0.079\sqrt{\frac{M}{b}}$.

Then, cubic feet of concrete per linear feet of beam =

$$\frac{0.079\sqrt{\frac{M}{b}} \times b \times 12}{1728},$$

and the cost of concrete per linear foot of beam is found by multiplying the latter expression by \$0.43, and equals $\$0.000236\sqrt{Mb}$.

The sectional area of steel, in this case, $= 0.0115 \times 0.079\sqrt{\frac{M}{b}} \times b$.

Its weight per linear ft. $= 0.0115 \times 0.079\sqrt{\frac{M}{b}} \times b \times 3.4$, and the

cost per linear ft. = the latter expression multiplied by \$0.05 and equals \$0.000154$\sqrt{Mb}$.

These figures do not include the cost of concrete in the beam below the steel, nor the cost of forms, but they give a good general idea of the relative costs of various combinations, for a simple beam or slab of one span, with no steel in the top of beam over the supports, and the breadth remaining constant.

To arrive at the comparative costs of continuous slabs which have the same amount of steel over the supports as there is in the center of the span, and half this amount in the bottom of slab at the supports, the quantities, and therefore the costs, of the steel as given in Tables 5 and 6 should be increased 25 per cent. The effect of this increase is shown in Tables 7 and 8.

TABLE 7.

SHOWING APPROXIMATE COST PER LINEAR FOOT OF CONTINUOUS SLAB OF DIFFERENT MIXES OF CONCRETE. STEEL STRESS 16 000 LBS. PER SQ. IN.
(Steel costs increased 25 per cent. to allow for laps.)

Mix.	Total Cost per Lin. Ft. of Slab.
1 : 1 : 2 . . .	\$0.000428$\sqrt{Mb}$
1 : 1½ : 3 .	0.000393$\sqrt{Mb}$
1 : 2 : 4 . . .	0.000382$\sqrt{Mb}$
1 : 2½ : 5 .	0.000385$\sqrt{Mb}$

TABLE 8.

SHOWING APPROXIMATE COST PER LINEAR FOOT OF CONTINUOUS SLAB OF DIFFERENT MIXES OF CONCRETE. STEEL STRESS 18 000 LBS. PER SQ. IN.
(Steel costs increased 25 per cent. to allow for laps.)

Mix.	Total Cost per Lin. Ft. of Slab.
1 : 1 : 2 . .	\$0.000406$\sqrt{Mb}$
1 : 1½ : 3 .	0.000376$\sqrt{Mb}$
1 : 2 : 4 . .	0.000366$\sqrt{Mb}$
1 : 2½ : 5 . .	0.000376$\sqrt{Mb}$

The additional amount of steel in continuous beams due to laps and stirrups varies in different beams but rarely exceeds 40 per cent. of the amounts used in Tables 5 and 6. The effect of a 40 per cent. increase is shown in Tables 9 and 10.

TABLE 9.

SHOWING APPROXIMATE COST PER LINEAR FOOT OF CONTINUOUS BEAM OF DIFFERENT MIXES OF CONCRETE. STEEL STRESS 16 000 LBS. PER SQ. IN. (Steel costs increased 40 per cent. to allow for laps and stirrups.)

Mix.	Total Cost per Lin. Ft. of Beam.
1 : 1 : 2	$\$0.000452\sqrt{Mb}$
1 : $1\frac{1}{2}$: 3	$0.000414\sqrt{Mb}$
1 : 2 : 4	$0.000401\sqrt{Mb}$
1 : $2\frac{1}{2}$: 5	$0.000400\sqrt{Mb}$

TABLE 10.

SHOWING APPROXIMATE COST PER LINEAR FOOT OF CONTINUOUS BEAM OF DIFFERENT MIXES OF CONCRETE. STEEL STRESS 18 000 LBS. PER SQ. IN. (Steel costs increased 40 per cent. to allow for laps and stirrups.)

Mix.	Total Cost per Lin. Ft. of Beam.
1 : 1 : 2	$\$0.000425\sqrt{Mb}$
1 : $1\frac{1}{2}$: 3	$0.000394\sqrt{Mb}$
1 : 2 : 4	$0.000382\sqrt{Mb}$
1 : $2\frac{1}{2}$: 5	$0.000390\sqrt{Mb}$

The figures for costs of continuous slabs (see Tables 7 and 8) may be said to represent the actual differences in cost of constructing slabs of the various mixes shown, as the cost of forms is the same in each case and the difference in cost of concrete in bottom of slab below steel is so slight that it is practically negligible. The 1 : 2 : 4 mix is evidently the proper one to use in cases where the bending moment determines the section.

The figures for costs of continuous beams (Tables 9 and 10) must be corrected as shown in the following example.

Assume the width of beam is 12 ins., and depth of concrete below center of steel is 3 ins., and the figures to be corrected are those of Table 9. For the 1 :1 :2 mix the cost per linear foot of concrete below steel is $0.25\times\frac{b}{12}\times\$0.43$ and equals $\$0.009\times b$. The cost of forms is $\left|(0.079\sqrt{\frac{M}{b}}+3)\times 2+b\right|\times\frac{12}{144}\times\$0.16$, which reduces to $\$0.00211\sqrt{\frac{M}{b}}+\$0.08+\$0.0133\times b$. Now, assuming a

bending moment of 1 000 000 in. lbs., it will be found that the cost of steel and concrete above steel is \$1.56 per lin. ft., concrete below steel is \$0.11, and forms are \$0.85, the total being \$2.52 per lin. ft. The total costs of the other mixes, in the order given in the table, are respectively, \$2.42, \$2.45 and \$2.60, the 1 : 1½ : 3 mix showing slightly better results than the 1 : 2 : 4 in this particular case, in which it is assumed that the bending moment determines the beam section. In case the section had to be increased on account of shear the results would be different and would depend on whether width or depth or both were increased. Under some conditions, where the section is governed by shear, a 1 : 1 : 2 mix might prove the more economical. In T-beams the stem section is frequently determined by shear, so in such beams it may happen that a 1 : 1 : 2 mix will be better for the stem, and a 1 : 2 : 4 for the flange.

It will be noted that in the above comparisons of cost it has been assumed that the breadth of the beam or slab is constant for all mixes while the depth varies. In cases where the same clear head room must be maintained, it is apparent that the richer mixes have an advantage due to their lesser depth which effects a saving in the height of columns and sometimes in the facing of exterior walls, which should be taken into account in making a final comparison of different designs. If for any reason it is necessary to have the depths of beams remain constant while the breadths vary, or to maintain a certain ratio of breadth to depth, it will be found that the choice as to economy will, at present prices, usually be between the 1 : 1 : 2 and the 1 : 1½ : 3 mixes.

Considering the fact that the prices of cement, sand, stone, gravel, steel and lumber, as well as labor, are constantly changing, it is doubtless impossible to devise a simple formula for determining the most economical mixes for the different parts of a structure. Those which are best for one building at one time may not be the most satisfactory for another similar building at another time. On the other hand, it is doubtless possible after preparing a fairly satisfactory design, to spend more time and money in an attempt to improve it than can be saved in material and labor when it comes to construction.

There are many firms of engineers and architects who prepare plans for buildings to be built by contract. They do not know what contractor will do the work, and sometimes they are not sure that they themselves will have supervision of the construction. Under these conditions they may not think it best to specify the use of different mixes of concrete for different parts of the superstructure. In many cases, the 1 : 2 : 4 or the 1 : $1\frac{1}{2}$: 3 mix is more economical for beams and slabs than the 1 : 1 : 2, and they may feel that it is safer to specify the use of 1 : 2 : 4 or 1 : $1\frac{1}{2}$: 3 concrete in beams, slabs and columns.

An engineering firm which maintains a reliable construction force might, on the other hand, feel no hesitation in specifying a richer mixture of concrete for columns, as in its case there is less liability of batches of 1 : 2 : 4 concrete being placed where 1 : 1 : 2 was called for.

In conclusion, the writer would say that he believes Mr. Mayer's paper is worthy of careful reading by any one interested in the subject.

J. R. Worcester.* — This paper is very timely in its suggestions and helpful in its information as to costs, particularly of those items of cost which an engineer not directly interested in construction finds it most difficult to ascertain, such as labor and cost of plant.

It may be worth while to point out, however, that the author has in one of his examples, presented figures which might be misleading if taken as too generally applicable. This is the table of comparative costs of seven different types of columns, pages 65 and 66.

The author does not state the capacity which this column is designed to carry, or the specifications by which it is designed, but the intention is evidently to make the different schemes of equivalent strength. This is not the result, if we follow the rules of the Joint Committee. According to these, scheme (f), which appears to be the cheapest, is not allowable because the longitudinal reinforcement is less than one per cent. of the area. Again, the other schemes, including spiral reinforcement (d) and (g), have about 40 000 lbs. capacity in excess of the types

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having no spirals. To bring them to the same basis of strength, four longitudinal bars could be left out in (d) and eight 1-in. bars could be substituted for the ten $1\frac{1}{8}$-in. bars in (g). These changes would reduce the cost of (d) to \$66.77, and that of (g) to \$65.99. The cost of (g) would therefore appear to be less than that of the (f) design, which is not allowable, and makes it appear that in this instance, at least, where allowance is made for the value of the space occupied, the smallest design is preferable.

LESLIE H. ALLEN.* — The reason for the apparent difficulty in comparing the costs of the different designs of reinforced concrete is due to the fact that there are so many variables to be taken into account. This is not the case in designing steel structures, as the only variables are the weights and prices of steel. In the case of reinforced concrete we have the labor and materials on concrete forms and reinforcement, and variations in stresses due to changes in the mix and the percentage of reinforcement. For this reason this subject as a rule is a rather difficult one for the consulting engineer.

Following Mr. Mayer's thought a little further, I might suggest that in some buildings recently designed by engineers we figured with them an interesting saving in design in the case of a building which carried different loads on different floors. It was found that by changing the mix of the concrete in the floors it was possible to keep the size of the beams the same on each floor, although the loads changed. The result was that on some floors we built beams and slabs that would not be economical if the same design was carried right through, but on account of the great saving in form work due to the avoidance of any re-making the whole building was a good deal more economical than would have been the case if each floor had been designed for the same mix.

BURTIS S. BROWN.* — I think we are indebted to Mr. Mayers to-night for giving us this paper. Not many years ago we could hardly pick up an engineering magazine without seeing presented some new formula for the economical design of con-

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crete. In nearly every number that came out some one would present a formula on economical design. With so many changeable factors entering into the economical design of concrete, one can see how absolutely impossible it is to incorporate them into a single formula. I think the principal value of this paper is that it educates the engineer's judgment in the design of concrete so that very soon, after figuring out a few of the designs, he is able to spot the most economical one without very much calculation of the special principle.

One thing that I think has to be considered where one is designing for a special organization is that that organization can take care of one type of construction more economically than another type. I remember, at one of the meetings of the American Society of Civil Engineers, I discussed with the general superintendent of one of the largest concrete construction companies in the country the question of flat-slab design, and he said that their company could build beam and girder floors even for heavy loads, much cheaper than flat-slab floors. They were better equipped to take care of that type of construction than they were the flat-slab type which some of the Boston specialists were using. There are those special conditions that must be considered and that the general practitioner has to think of, which a concern that is built up to handle a special type of construction does not have to think of so often.

In working out the most economical design of beams, it has been my practice to try several different depths of beams in order to make sure I am getting the most economical beam for each different layout, and I might say in one of my jobs that by studying ten different layouts I was able to get a design that saved fifty thousand dollars over the design first proposed by the people who were intending to build the structure.

JOHN R. NICHOLS.* — I want to endorse what Mr. Mayers has said about the necessity of making engineering designs, and it is a great pleasure to find one's own ideas so corroborated.

The thing that struck me most emphatically was something to the effect that the design of a window is of prime importance. "Prime" is the right word to use. Not more than five years

* With Monks & Johnson, Boston, Mass.

ago the steel sash companies would make us a window to fit any opening and with glass cut to any size whatever. But within the last five years that has all been done away with and they now issue their catalogues showing certain standard sizes of sash. The design of a window for the opening has a great deal of influence on the cost of the building. I have some tables here of steel sash sizes, and I have picked out a window, the only one that fits a 17-ft. 6-in. bay. That is the smaller window of the two Mr. Mayers has used, and it uses 12-in. glass and has five units, which means it has four mullions. Each mullion costs two or three dollars, depending on the length, and the use of 12-in. glass means that you have a large number of muntins. What I am getting at is that the use of a large number of mullions and the use of small glass means expensive sash. If he increased his window size to 17 ft. 6 in. he can use 16-in. glass with three units, and there he has saved quite a lot of muntin and a whole mullion. If he cut it down, on the other hand, to 17 ft. 4 in. he can use 16-in. glass and only two mullions. This is using United Steel sash. Other makes give a different variation in the sizes, but the principle is the same. The point is this: When you are designing a building, and considering the center-to-center distance between columns, the thing to pick out first is the window you want to use. Then design your column. If you want to get the sash quickly, and the height is determined, and you have got to use 20-in. high glass, in case you wish to use just twelve feet in height you have got to use ten lights. The nearest thing in other sizes is 18-in. glass, eight lights high. Some makers of glass will give you quicker delivery on 14-in. by 20-in. glass size than on 16-in. by 20-in. Thus we see that the design of a window is really of prime importance.

Another matter of importance is the floor space occupied by the exterior column. It doesn't look as though the exterior column occupies a great deal of floor space, but those engineers who have to do with heating these buildings have to run pipe coils by those windows, and don't like to bend every pipe coil around those columns, but like to keep them flush with the wall. There the floor space occupied by wall columns is again a very important feature.

One of the most bewildering unit costs that comes to the engineer in the comparison is the cost of forms when they are to be used once, or where used two or three or four or five times. In many cases, — when we design a boiler house, for instance, — that is only one slab, the roof, and when that is poured the forms are just lumber. I take it that the thirteen or fourteen cents given here wouldn't apply to such cases. On the other hand, I have known of flat-slab forms being used over and over again, and those using them have stated that they cost somewhere near six, seven, or eight cents per square foot. That element is one of the most difficult to deal with in making comparisons of this nature.

MR. MAYERS.*—The cost of forms as I have tabulated them in the paper is based on the ordinary construction of buildings five or six stories high, using them probably three times. The cost of forms when used in a building like that, if used three times, the material cost of one board foot is really used in the unit cost of the forms. The amount of form lumber actually used per square foot of contact surface may be taken at three board feet. Thus, when forms are used but once, it is necessary to estimate on three board feet of material instead of one board foot, as would be the case when forms are used over three times. In the boiler house roof form cost you would have to add to the units in the paper the cost of about two board feet of form lumber, but your salvage would be much more for the lumber where it had been used only once. Generally speaking, if forms are used only once I should figure at least two board feet of lumber more per square foot of surface measurement. I might say, however, that in the comparative costs it would not make much difference what price you used. You have to know more about the conditions and more about the unit costs to price the work for estimating the actual costs. I have been careful to state that those unit costs would not do for use in making an estimate.

Throughout the paper under discussion, stress has been laid on the fact that these designs are of value only in so far as they are representative of quantities of material on which to make comparative estimates for the sole purpose of illustrating

*Author's closure.

the methods of estimating concrete work. Designs were selected which contained various percentages of reinforcement and various mixes of concrete, and are given here in order to illustrate the methods of estimating costs only. The computations for the various designs have been in most cases purposely omitted, as it is the author's intention to have the reader of the paper concentrate his attention on the methods of estimating the cost of the work. If these designs had been given in detail it is quite probable that the paper would lose much of its force as an exponent of estimating methods, as it would then offer an excellent opportunity for an engineering discussion instead of a discussion on the principles of comparative cost estimating.

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PAPERS AND DISCUSSIONS

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THE CAMBRIDGE, MASS., SYSTEM OF REAL ESTATE ASSESSMENT.

By Stoughton Bell, Esq.*

Your President has spoken briefly of the organization of the commission in Cambridge, which was appointed by the mayor at the request of a citizens' meeting. Its purpose was to look into the subject of real estate assessment in Cambridge. As originally appointed it was a commission of five. We have a fortunate arrangement in Cambridge with the Massachusetts Institute of Technology and with Harvard University by which the mayor may request the heads of each of those institutions to designate some one to assist in municipal work. Harvard appointed, at the mayor's request, Professor Bullock, who is now president of the National Tax Association and the head of the Department of Economics at Harvard, — a thorough expert in taxation matters. Technology appointed your Presi-

[Note. — The President of the Society, Charles M. Spofford, who introduced the speaker, stated that the committee of which Mr. Bell was chairman was appointed by Mayor Good, of Cambridge, and consisted of Cambridge business men supplemented by a representative of Harvard University and a representative of the Massachusetts Institute of Technology. This committee, after a careful study of systems of real estate valuation in other cities, decided to appoint an engineer to make a detailed study and devise a system for Cambridge. Mr. E. O. Christiansen was appointed for this work.]

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dent, Professor Spofford, the head of the Civil Engineer Department. We were appointed in December, 1914, and for three or four months made an investigation of assessments in the city of Cambridge. We also made an investigation of assessments of the cities and towns throughout New England, and in March, 1915, reported to the mayor that it was our belief that the city of Cambridge could introduce a plan which would value all real estate on a proportionately equal basis. We recommended and asked that the committee to establish the system, when appointed, should have an appropriation and should have an engineer to take charge of the work, and we recommended the adoption of the system which was later put in force.

That recommendation was acceptable to the mayor and the city council. An appropriation was granted and an engineer appointed, who was sent to make investigations in cities which had systems already installed in other parts of the United States. He went to Newark, Buffalo, Baltimore and New York, where offices were opened to him for a very complete study. We had made a very careful survey of the situation in Cambridge, and had utilized all the departments of the city that we could for assistance. One of the most useful was the planning department. We asked them to tell us something about assessments in the city of Cambridge, — if they could not picture them for us so that we could see them with the eye as well as look at the figures, — and they worked out a scheme of coloring the map of the city. The highest valuation, shown in black, was at Harvard Square and at Central Square. The white areas represented land assessed under five cents per square foot, and the black areas land valued at fifteen dollars per square foot. Here is a thing I like to point out when I am calling this to any one's attention. We have recently had a good deal of agitation in the legislature concerning the burden upon the city of the exempted property of the University. I like to point out that the most appreciable area of high-priced land in the city is immediately southwest of the College yard, which is exempt. There is a little that is high at Central Square and a little bit at Porter's Station, but at Harvard Square is the property that is the most highly valued in the city.

Assessments in New England are a growth of long standing. The assessors have, in the majority of instances, found the value upon their books, and have had no machinery and no method by which they could revalue the entire city. They have gone into districts and placed a higher or lower value in that district, but so far as we could find from our investigation there has been no machinery placed in the hands of any assessors in the New England States that would be of any real assistance to them in placing a fair value upon land. Here is an illustration of the result. There is a little rooster-shaped piece of high-valued land located in the Norton estate, which is undergoing development. I think it is a fair deduction to say that the reason that high-priced land lies in a lower-priced district is because that land has been developed and has been called to the attention of the assessors, and the result has been that where a new house has gone up an increase has been put upon the land under it.

The assessors of the city of Cambridge had the best lot and block maps that we found in any of the New England States. These were in existence when we took hold of this work. But in order to see any large district it became necessary for the assessors to put a half dozen tables together and then place the maps one against another, and should one of the assessors' coats push against the picture puzzle it was gone and had to be readjusted. These lot and black maps covered the entire city of Cambridge. They showed the streets and the lot lines, the kinds of construction, wood in yellow, brick in red, stone or cement buildings in gray, etc. Such maps are absolutely necessary, we believe, for any assessors' offices, and in this instance they were the only plans which were in the assessors' offices. They had asked for appropriations for large maps but had been unable to get them.

Besides these, we had a study by the planning board with the values represented in color, and another plan showing by cross-hatching and other symbols the character of the development in different parts of the city. With that map and with other maps which will be made, the assessors may see how the development is changing from year to year, from the effect of houses going up and the large increase of apartments which will occur, largely

due to the subway connection with Boston. The map gives a bird's-eye view of the purposes to which property is put. In addition to that, we had a clerk go to the registry of deeds and obtain for us, during the time that the war tax was on, the consideration of deeds as expressed in stamps. We had a record of recent mortgages which were put on property, and we made a careful study of rentals throughout the city, and these we had expressed in color form on a map. The rentals ran from $15 to $20 in dark blue up to $20 and over in yellow. Brown represented $10 to $15 and pink from $5 to $10. Whenever we saw a sign in a window "For Rent," we found out what the asking price was; and we kept the telephone wires busy for a little while, getting the figures for this chart. An interesting thing shown on this map is a comparatively high rental section, on the top of a knoll in East Cambridge, and around it the rentals run low. This map afforded another opportunity for studying the development of the city and of assisting the assessors in getting at a fair value.

Then we made a study of the lots and blocks in the city in order to find out what the standard size of lot might be. In Baltimore the standard depth of lot is 150 ft. In Cambridge we found that by far the greater number were 100 ft. in depth, and we therefore took this as the standard depth.

The foregoing might be called a preliminary study in order to inform ourselves — and, by the way, throughout the time these studies were going on we had frequent hearings. We had various representatives of assessing bodies come before us; we invited the real estate men of the city to come before us and give any suggestions; and throughout our work I want to say that we had the heartiest coöperation of the trustees of savings banks and the real estate men of Cambridge. The Cambridge Real Estate Exchange gave us enormous assistance in the way of suggestions in our work before we turned it over to the assessors.

When we had finished this preliminary study the question at once arose what sort of a unit we should use, for, if we were going to compare one part of the city with another, we must have a common unit with which to make the comparison. In

New York and Baltimore and the other cities which have adopted a system, the front foot, so called, is used.

I do not need to tell engineers what that is, one foot on the street and one hundred feet deep; but we in New England are not in the habit of thinking of front feet. All our sales are made on the square-foot basis, and yet we were unable to find any city that had adopted a square-foot unit. We made considerable study to see if the front-foot unit could be used in the city of Cambridge, and we decided there was no particular reason why it should be used, and that if we attempted to use the front foot, the system would not be such that it would furnish a method of conversation between the assessors and the citizens, and that is what we were working for, — some common language so that the assessors and the citizens might talk with one another and not have a citizen come in and say, "I do not believe your value is right," and have the assessor say, "We believe it is right," and simply split on opinion on these matters. So we adopted the square foot as the unit.

It is a well-known fact, that, where there are two lots side by side, one 50 ft. deep is worth more than half as much as the lot of the same shape and frontage which is 100 ft. deep. Just how much more was another problem which we had to solve. Then the proportion is not the same in the residence as in the business districts. There have been various rules for the enhancement of values of a lot due to the corner influence, — that is, the increased value of a lot because it is located at the corner of two streets. And the last thing we went to work upon was the equalization map. With regard to the standard depth of lot, it might be of interest to you to have a few figures. We have in Cambridge some 932 blocks. Of these, 74 per cent. are divided into 100-ft. lots and 26 per cent. into lots of greater or less depth.

A word more in regard to the long and short lot rule of proportional value of lots of varying depth. In 1866 Judge Hoffman in New York ruled in court that a lot 50 ft. deep was worth $66\frac{2}{3}$ per cent. of a lot 100 ft. deep. That has been held for some time in the city of New York. In Cambridge we plotted actual sales, mortgages and capitalization of rentals on a chart on

which abscissæ represent the depths of the lots and ordinates per cents. of unit values. Then we drew a curve representing the increase of values in a foot of short over long lots. We did this for the business districts and for the residential districts. We compared these curves with the ones we had obtained from New York, Buffalo and Baltimore by placing them upon another chart. Newark was one of the first cities to adopt a systematic method of assessment, and they had a good system but they never had it on a chart. When we had plotted their figures on a chart we found certain irregularities which they admitted they had not noticed until the curve representing the figures had been called to their attention. A table of comparisons was then worked out. For instance, for a depth of lot of 25 ft. the value in New York is 41.7 per cent., and in Newark it is 50 per cent. in the business and 37 per cent. in the residential district of the values for 100 ft. lots. In Cambridge the old line of assessment ran back almost straight until it got beyond 100 ft. in depth. The figures had never been plotted for Cambridge although the assessors appreciated that lots much more than 100 ft. in depth were proportionately of less value. They had not, however, worked out this curve in actual assessments. We placed these charts before the Cambridge Real Estate Exchange and asked them to criticize them. They said they thought we had made a mistake in our residence chart, that we went back too quickly in the very shallow lots. We asked them why. They could not give us any figures, and they said perhaps we were right. We found after one year's practice that the real estate men were right, though they could not convince us that we were wrong; but the actual application of the figures has shown that to us, and the curve for residence districts will be somewhat flattened in future.

Now, to illustrate the application of the depth curves to lots of various depth. Suppose we assume a lot on a street having a ten dollar per square foot unit, the lot to be 50 ft. in frontage. Obviously, under these conditions a lot 100 ft. deep containing 5 000 sq. ft. would be worth $50 000, since the 100 ft. depth is the standard, and each square foot is worth 100 per cent. of the unit. Now, suppose we find the value of a lot 75

ft. deep; we turn to our curves or long and short lot tables and we find for business sections that every square foot of a 75 ft. lot is worth 117 per cent. of the unit; thus the unit value per square foot for this lot would be $11.70, and since the lot contains 3 750 ft., the total value of the lot would be $43 875. Application of these rules for lots in residential sections is similar to the illustration just given.

In order to simplify the work for the Board of Assessors, the committee worked out a coefficient for each of the twenty thousand odd lots in the city of Cambridge, depending on its depth, shape and location. This coefficient represents all the factors entering into the assessment of any particular lot except the unit value placed on the equalization map by the assessors. In this way it is only necessary to multiply the coefficient by the unit value to obtain the assessed value of the lot, the coefficient, of course, remaining the same until the lot is cut up.

We have also applied a method for obtaining the enhancement value of a lot because of its location at a corner. Mr. King adopted a plan, some years ago, and that was followed originally in New York. New York now treats the lot as fronting on the main street, and adds a definite percentage of increase to the value of that lot and says that is the increased value due to the side street, an arbitrary percentage throughout the city. Mr. Bernard, a special tax deputy in Baltimore, worked out a more equitable plan, we think. He found the value of the lot as if it fronted on the main street and took one half the side street value and added it to the value on the front street. That gave him relative valuation of the side and front street as to that lot. In the business district of Cambridge we found the value of the lot on the main street and value of it on the side street and added to the value on the front street twenty-five per cent. of the value on the side street, and that seemed to work out pretty well.

There are a few minor factors of value which were worked out in some places. One of them is where a particular lot is located, or a series of lots are located, upon an alley; for instance, these two lots had an alley between them. In cities where there are many alleys the increase due to the alley influence has to be

worked out, but in Cambridge we do not have enough to give us data upon which to base a definite plan, and therefore we did not attempt to lay out any rule for the city. There is another factor which enters into the question of value, and that is the question of plottage. A large tract of land in a certain location is very much more valuable because of its size than it would be if cut up into smaller lots. That of itself must be taken into consideration in making assessments; but we did not, owing again to lack of information, work out any definite rule in Cambridge. We did work out an equalization plan on what is known as an "equalization" map. That was nothing more or less than a map of Cambridge with the streets laid out a little wider than they ordinarily would be, and main public buildings located all without regard to lot lines. Now, the use of this equalization map is to do away with that picture puzzle I spoke of earlier in the evening (that is, the patching together of this lot and block collection of maps), and thus give the assessors and the citizens of Cambridge an opportunity of comparing the units, one with another. Given a unit of one square foot, the problem was up to the assessors to place the value of that unit upon every side of every block in the city of Cambridge, irrespective of lot lines; irrespective of anything except the value of one square foot located on the street on every side of every block. It gives the assessors an opportunity of getting a bird's-eye view of the city, of placing the unit value at the highest point at Harvard Square and another one at Central Sauare, and then of grading values to the lowest point between these two. That in itself is of enormous value to the assessors. It gives them an opportunity of studying large districts in the city. We believe it will be of enormous assistance to the county commissioners, for most of the appeals are taken to the county commissioners in Cambridge — the assessors being Democrats and the county commissioners Republicans.

We believe that when that is presented to the county commissioners this year some of the values that have been placed by the assessors in Cambridge will not be hacked quite as badly by the county commissioners. But neither of these purposes is of the greatest value. The greatest value is that you and I as

citizens can see whether our property is valued on the same basis. We may pull down these maps in the assessors' office and may argue that our land located here is valued at a certain amount and we believe it should be valued less or more. In other words, it gives us a common language in which to talk with the assessors.

Now we turn to the method of valuing buildings. In the first place we made a study of the different units of value in actual use to-day, and we decided that the cubic foot was probably the most inclusive value and was the unit we would adopt in Cambridge. We then made a study of the different kinds of buildings and divided them into sixteen different groups, — garages, single houses, double houses, three apartment, etc., and then we subdivided these groups into kinds of construction. We then worked out a table of maximum and minimum values. We consulted all the contractors, engineers and architects that we thought would give us an opinion. We turned the matter over to the Boston Society of Architects, and secured the assistance of individual members of their association, also Stone & Webster, Aberthaw Construction Company, etc., who helped us to work out a maximum and minimum value of a cubic foot for each kind of building with the different kinds of construction. Then we worked out a table for percentage of depreciation which should be applied to each one, and that was also approved by the different organizations and individuals whom I have mentioned. We turned over all this information at public hearings to the citizens of Cambridge. Throughout our activities we tried to keep in as close touch with the citizens as we could, for we knew that they were the final judges and that if they did not approve the work we were doing it would not be worth much; and we invited their criticism when we worked out these problems. We had public hearings and one man attended who did not understand exactly what the tables stood for, and he was the only one who came to that public hearing. So we felt that we were pretty nearly right.

Having completed the unit value and table of depreciation, we had every building in the city inspected and measured. We made a record of the kind of construction, the finish, the kind of

plumbing, and condition of repair. All of which information appears on the card catalogue with the unit applicable to it.

We worked out also a few forms for use in the assessors' office. In the old days we had land set off by wards. We had eleven wards in Cambridge, each ward in a different book, and, in order to be sure you had covered all the land a man owned in Cambridge, you had to go over all those books. That has now been changed by the assessors' office. They have now arranged the entire record of property in Cambridge alphabetically.

It is with a good deal of pride that we say that the tax commissioner of Massachusetts issued a pamphlet of instruction to assessors some months ago, and in that little pamphlet, copies of which I have here, is a brief description of the Cambridge system of real estate assessment. The interest in this system from outside, as the President has said, has been very great. We have had inquiries from many places, and to-day I received one from Greensboro, N. C. We had one from the appraiser of the Interstate Commerce Commission in Minnesota, and from a large number of cities and towns in New England.

That constitutes the machinery. Now perhaps you would like to have a word in regard to its application in the city of Cambridge. As soon as we turned this matter over to the assessors, the first piece of work for them to do was to take the equalization maps and place upon them the tentative values of the unit. That was a considerable piece of work. They did that throughout the city, and then we went about from one district to another throughout the city. I am sure it is the first time in New England, and I think it is the first time including most other cities and towns, that the assessors have asked the assistance of citizens in fixing a fair value of property. Having placed these tentative values, hearings were given throughout the city, and the citizens came in. In one district, the one in which I live, they were there in force. They thought the whole thing was all wrong, and the assessors did not know what they were doing. The unit was too high throughout the district. We asked them how about the comparison of values. They had not looked at that. We asked them how land on the main

street compared with land on the streets leading off of them, and they said about one hundred dollars to eighty dollars, etc. They looked and found that the assessors had so placed them; and they found that throughout that district, except in one or two instances, the relative values of the unit had been very carefully placed and were not subject to criticism. When they found that the particular lot they owned was not being gouged, and that they were not being made goats of in this proceeding, most of them decided that the method was pretty fair. The amount of assistance that the assessors obtained from these hearings was enormous. We had stenographers present. One man would say that the unit value on his street was too high, and the chairman would ask him how it compared with the same piece on the next street, and he would express an opinion, without consulting the tentative value on the map, and in most instances we found the assessors were pretty nearly right. There were some cases where changes were made, but that the assessors were looking for. They appreciated that and made the most of it. Then, having all that information, they worked out their final assessments, and the bills came out in October and November. In November we held a municipal election. The chairman of the board was running for reëlection. He was opposed by an ex-assessor who was a member of the board of aldermen, a very popular vote-getter, and the attack was on the Cambridge system. The chairman of the board was re-elected by over two thousand majority, which is a good majority in the city of Cambridge in these days. That was immediately after the bills were out.

Now, a word or two on the dollars and cents. In 1916, the total assessed value of land alone in the city was $45 135 700. In 1917 this jumped $7 704 700, to $52 840 400. The value of buildings in 1916 was $63 133 000 and in 1917 this increased $304 000, to $63 437 000, a total increase of over $8 000 000. That is not all due to the adoption of this system. Comparing that increase with the average of the years 1912, 1913 and 1914, — and I take these three years because from the year 1914, when we began working on this system, the assessors did not put on the ordinary increase in real estate, — the average in-

crease was practically one and a half million dollars. The average increase in buildings in those three years was over two million dollars, a total of three and a half millions against an increase of eight millions; and I am told by the assessors that there was just about as much increase in building in the year 1917 in Cambridge as there had been in those three years. In other words, the result of the application of this unit to the buildings in Cambridge was greatly to reduce their value. It may be of interest to you to show the result of studies of the relative values of land. Take an industrial block in East Cambridge. In that particular block there were 13 lots. All of these 13 lots show an increase. The maximum on one lot is 100 per cent. and the minimum increase, one lot, of 20 per cent. In another poor-class residential block but with good demand, there were 58 lots. One shows a reduction in value of 25 per cent.; 13 remain the same as before; and 34 lots are above in value. A business block in Central Square having 27 lots has 6 which are below the valuation of the year before and 21 above. The greatest is 12 per cent. below, and the greatest increase is in a little bit of a lot which really is not worth considering, where it is over 200 per cent. increase; but that is a little bit of a lot which had been overlooked in a previous reassessment and is, I think, the only lot which has an increase of anywhere near that percentage in the city. Then in a block containing dormitories changing over to apartments in Harvard Square, there are 35 lots; 22 show a lower valuation in 1917. The minimum is one tenth of one per cent. and 13 are increased in value, the maximum being 26 per cent. Another industrial block, on both sides of a railroad, has 18 lots, all of increased value, the maximum being 96 per cent. and the minimum $3\frac{1}{2}$ per cent. That gives you an idea of how valuations change when you place a systematic plan in operation.

DISCUSSION.

MR. JAMES J. CASEY.* — I came here to-night upon the invitation of Mr. Hastings, engineer for the city of Cambridge, to listen, rather than to talk, as I wanted to hear our system discussed by the members of this Society. I am glad, however,

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to give to the meeting the benefit of our experience with the system.

As it happens in most instances where a change is made from one system to another, even though the study and preparation cover a period of years, when the time arrives to put the change into operation there is much haste and confusion. Therefore due care cannot always be given to every detail which would make for a complete and correct revision of real estate values. Moreover, we were rather unfortunate in the year that the system was installed; war times were upon us; money was scarce, and it was difficult to maintain values. It was late when the tax bills were sent out, and because of this delay and the previous discussion of units, which were not always understood, there was more or less unrest in the minds of the taxpayers. When the people finally learned the result of our work and it was explained to them, they were, generally speaking, satisfied that we had accomplished what we had set out to do — that is, to equalize values, and that the assessment for 1917 was nearer correct than ever before. Please bear in mind that the object of the system is not to raise values but to equalize them.

We had, however, an increase in land values over 1916 of about seven and three-fourths millions of dollars, or 17 per cent.; a substantial increase for Cambridge. The area of the city is only six and three-fourths square miles, with one and one-half square miles of this area exempted from taxation and another square mile unfilled low land.

The main criticism of our new assessments was of the units, not of the system. During the abatement season, many taxpayers whose land had been assessed higher than in former years came in to learn the reason why. We very carefully explained to them the plan under which we were working; compared their land with other land in the vicinity; showed them that all owners must be treated alike or the system would be worthless, and that equalization of the burden of taxation was our aim. I am glad to say that in the great majority of cases they went away satisfied that all were receiving the same treatment, admitting that their land was worth our assessed value.

Of course we do not claim perfection for our work in the first year; but we do promise better results from year to year, and hope to have it perfected within three or four years. In New York, where they have a similar system, it took about eight years to become readjusted to the change.

I think there should be a change in our table of percentages of relative value affecting short lots. In my opinion, this class of lots carries too high a percentage of the standard lot, particularly in the residential sections of the city.

Unfortunately there was not sufficient time to review the new building values. Our table of units of reproduction and allowance for depreciation was substantially correct, but the buildings were not always put in their proper class. This condition was not very serious and was comparatively easy to rectify.

Our office was fortunate in the possession of accurate block maps upon which lot lines were drawn to scale. These block maps are corrected and kept up to date by the city engineer, from tracings of plans of lot subdivisions filed at the Registry of Deeds.

For many years the assessors of Cambridge have asked the city government for money for equalization maps, but with no success. The special tax commission immediately saw their necessity and provided them.

Having the necessary tools, we then placed a unit of land value in every street, as shown on the maps. This was obviously the important feature of our work. A coefficient had previously been worked out for each lot in the city. To get the value of any lot, the coefficient is multiplied by the unit. These coefficients have a degree of permanency and remain the same until the lot lines are changed. The unit of value is always a more or less varying figure. Should it be changed it would be a simple matter for the office clerks to multiply the coefficient by the unit to get the value of the lot affected.

We have in our files a complete history of every building in the city. This information was gathered by men who were sent out to measure the buildings so that the cubic contents might be computed. The same men again went out to note

the class to which the building belonged; its construction, its age, its use, the number of rooms, how finished on the exterior and interior, its condition, rentals, and the condition of the street. From this information we were able to apply the unit per cubic foot for reproduction: also the depreciation to be allowed. This data is not only invaluable to the assessors, but to the public, because of its availability.

This yellow card (Figs. 1 and 2) is a sample of our office cards, and is reproduced on page 44 of the pamphlet issued by the tax commissioner. Upon this card is entered, on one side, the area, coefficient, unit and value of the particular lot of which it is a record; also all information pertaining to the building, cost of reproduction, depreciation and value, for assessment purposes. On the other side is written the location of the property, the name of owner, value of the land, value of the building and the total value. From this, our tax list is written as well as the book that is sent to the tax commissioner.

With regard to the coefficient used, where there are restrictions I would say that the coefficient is determined in every instance by the application of our table of percentages of relative value to the depth of the lot, and remains unchanged regardless of restrictions. Allowance for restrictions is made in the unit. The assessors do not always have knowledge of restrictions. The public meetings that were held to discuss land values aided us in learning about streets so affected.

Our coefficients were computed by competent men in the employ of the commission. These computations were made in books provided for that purpose, and are a part of our office records.

The assessors are able to make any changes that might happen from time to time. This is the advantage of the Cambridge system. There is no secret formula for the working out of any problem, and every feature of the plan is easily understood and readily applied.

Mr. Albert B. Fales.* — Mr. Bell mentioned the fact that in sending out a little pamphlet of general instructions to the assessors throughout the Commonwealth, in 1917, the tax commissioner's department took occasion to review in a very

* First Assistant Tax Commissioner of Massachusetts.

HOUSE NO.	NAME OF STREET	DIST. No.	BLOCK	LOT	RESTRICTIONS
206	*Cambridge*		*12*	*8*	*None*

BLDG. CONSTR. OR MOVED ON LOT IN 1905 PERMIT No.

RENT, ETC. *Occupied by owner*

REMODELED, REPAIRED, ETC. *Original condition*

GROUND AREA	HEIGHT	CUBIC FEET	CLASS.	UNIT	DEP. %
40 × 25	*28*	*28000*	*S. H.*	*.18*	*1½*

CORNER *No.*

ALLEY *No.*

PLOTTAGE *50 × 80 Rectangle*

COMPUTATIONS

50 × 1.08 × 4000 = 2160
40 × 25 × 28 = 28000
.18
5040.00

AREA	MULTIPLIER	K
4000	*1.08*	*54*

	LAND			BUILDING		
YEAR	UNIT	K	LAND VAL.	DEP.	AMT.	BLD. VAL.
1915	*.50*	*.54*	*2160*	*.15*	*756*	*4284*
1916	*.50*	*.54*	*2160*	*.165*	*832*	*4208*
1917						
1918						
1919						
1920						
1921						
1922						
1923						
1924						

Class
Bungalow
—Single House
Two Family
Three Family
Apartment
Store Building
Office ,,
Factory ,,
Storage ,,
Stables
Garage, Private
Garage, Public
Theatre
Club House
Miscellaneous

Foundation
—Brick
Stone
Concrete
Pile

Basement
—Full
Half
Quarter
Cement Floor
Waterproof

Construction
—Frame
Brick
Tile
Blocks
Stucco
Re-Concrete
Mill
Semi-Mill
Steel Frame

Exterior
Clapboards
Siding
—Shingles
Stucco
Paper
Press Brick
Com. Brick
Galv. Iron
Stone
Terra Cotta
Concrete

Heating
Stove
—Furnace
Hot Water
Steam
Combination
Sprinkler

Light
Oil
—Gas
Electric
Acetylene

Plumbing
Common
—Individual
Open
—Set Tubs

Floor
Common
Re-Concrete
Concrete Slab
Mill
Bay
Thick
Waterproof
Finish

Ceiling

Finish
Plain
—Hardwood
Halls
—Wood
Terrazzo
Marble

Roof
—Shingle
Slate
Tile
Gravel
Prepared
Asbestos
Metal

Flat
—Hip
Gable
Gambrel
Dormers

Windows
—Plain Glass
Wire Glass
Shutters

Miscellaneous
Elevator
Sprinkler
Fire Escape
Refrigerator
Vacuum Cleaner
Safes and Vaults
Telephone Equip.

Fig. 1

WARD / PR.	LOCATION *206 Cambridge St.*		RES.	NON-RES.		BLK. *12* / LOT *8*
YEAR		DESCRIPTION	Bld. Val.	Sq. Ft.	Land Val.	Total Val.
1915	*William H. Smith* / *206 Cambridge St.*	*Single Dwelling*	4284	4000	2160	6444
1916			4208		2160	6368
1917						
1918						
1919						
1920						
1921						
1922						
1923						
1924						

Fig. 2.

brief way, as was necessary in such a document, and in terms which would be readily understood by the average man, — and the assessors throughout the Commonwealth, generally speaking, are average men of the town, — the principles underlying the Cambridge system. That was done with the hope of encouraging the assessment of real estate by a system which would afford a means of comparison between different parcels of land better than the old rule of thumb or guesswork. It is perfectly true that in a small town the board of assessors, composed of good average men of the town, can go out and view the parcels of real estate and value them quite accurately, — almost with surprising accuracy, simply from their general knowledge of the values in the town. They know every sale, and they know every mortgage, and they know all the gossip of the neighborhood. They know the soil and the farms and about everything that is to be known about those properties, and they do reach very close values in that way. But when you get into the cities, and particularly our larger cities in Massachusetts, that rule of thumb falls down. In the first place, as your city grows it becomes impossible for three or any other number of assessors to visit all the real estate together so as to give their judgment as a body on each parcel of real estate. The first thing that happens is that the board of assessors divides the work into as nearly equal parts as possible among the three men, and each man goes out and views a separate territory. Your troubles just at that point begin to magnify. One member of the board is an optimist, and everything looks good to him, and all his real estate is valued up pretty well. The other man by temperament is a pessimist, and nothing looks good to him, and his values are very low. Equalization drops out of the thing right at that point. And then as the size of the city grows the difficulty increases. I feel very strongly, and I am willing to say it in the presence of some members of the Boston assessing department who are here this evening, that Boston is very much in need of a system of real estate valuation. As a matter of practical working, fifty men in Boston go out in fifty different districts and work with very little regard each to what the other is doing, and the result of such work does not tend to uniformity.

There ought to be a system by which the board of assessors could keep under its control what is to be done in the various districts by the various men that handle those districts. And it has been a matter of great satisfaction to the tax commissioner's office that the city of Cambridge waked up to this necessity and took the matter in hand. We feel that they have done an excellent piece of work; that the committee of which Mr. Bell was chairman has accomplished the laying of the foundation of a system of taxation which is applicable in Massachusetts better than the systems that are in use in other states in the Union, chiefly for the reason that all of their tables and curve values are made on the square foot basis. Of course here in Massachusetts we buy and sell and discuss real estate by the square foot, and the average citizen does not know much about what you mean when you attempt to tell him that certain land on a certain street here in Boston is worth ten thousand dollars a front foot. Now, as a matter of fact, the front foot rule does not mean anything taken the country over. In New York it means one foot on the street and one hundred feet deep, because that is the way they figure in New York. In Baltimore it means one foot on the street by one hundred feet deep, and in some of our western states it means one foot on the street by one hundred twenty-five feet deep. We have to know the city we are talking about before we know what a front foot means; but here in Massachusetts we all know what a square foot means, and all the computations for the city of Cambridge are made on the square foot basis. I consider that very much better for Massachusetts use.

Mr. Frank O. Whitney.* — I have been very much interested in the description of the work of the assessors in Cambridge. I have not heard very much said about the making of the plans. It seems to me that no system can be practically applied without a reasonably accurate plan to start with. You can assess by the square foot after you know how many square feet there are, but not until then. You cannot assess by the cubic contents of the buildings unless you know the size of the buildings. I do not know whether in Cambridge they had an accurate plan, or reasonably so, before they started. My experience has been

* Chief Engineer, Street Laying-Out Department, City of Boston, Mass.

entirely in the city of Boston, and I have been surprised in the number of years that I have had more or less to do with the assessing department of the city, — using their records a great deal, — to find how good their work was considering the fact that they did not have a comprehensive plan to start with. In some cities like Philadelphia and, I think, New York, — and I presume Baltimore, — they have complete block plans which show dimensions and areas of every lot from actual survey, and the buildings plotted to scale. In Boston it has been the custom, I think, of the assessors to watch carefully the registry of deeds. When plans have been made of individual lots they have had access to them and have made copies of them; and in cases where owners thought they were not being correctly assessed, especially where they thought they were being over-assessed, they have had plans made of their own property, and the assessors have been always ready to accept these plans when made by reputable surveyors. But, so far as I know, the assessing department of Boston has been handicapped by not having a complete plan of all the property in the city, and for that reason a great many errors have been perpetuated and a great many errors were originally made, because there was not that accurate foundation. In the old days they were not so careful in making deeds as they are to-day. I have known cases — for instance, in Hull Street in the North End — where deeds gave the depth of the lot as 100 ft. and the transfers down to the present time had simply recited that fact, whereas measurements showed that the lot instead of being 100 ft. deep was about 94 ft. deep. There was a case of over-assessment if the square foot was regarded. Boston has been made up by the annexation of a number of other municipalities, and errors which existed in the old times in those places have naturally been perpetuated, and sometimes errors have crept in on account of changes that took place about the time of annexation. I remember one case that came to my attention in 1895, in Roxbury. In 1868 Roxbury was annexed to Boston. In 1867 Longwood Avenue was extended to Brookline Avenue. Included in that extension was a certain piece of land fifty feet wide and one hundred feet deep. It was late in the history of Roxbury, and the

Roxbury assessors turned over the records to the Boston assessors, without correction, and the change was lost sight of. The owner made no objection, and until 1895 that piece of land was taxed to the prior owner. It was an estate in the hands of heirs, and when they wanted to sell the property they found they owned five thousand feet less than they had supposed. Of course there was no redress, — they had paid taxes for nearly thirty years, and it was as much the owner's fault as the assessors'. There have come to our attention many cases where untaxable property has become taxable property. Take, for instance, right here in the heart of the city, the block bounded by Washington, Summer, Chauncy and Avon streets, where the Jordan Marsh and Shuman properties are located. His honor the mayor requested our department to make a survey of that block to test whether much that had been said in regard to the areas in the business district was correct. We found in that block, on account of passageways which existed when the block consisted of a large number of smaller estates and which were afterward consolidated and the passageways covered up, that these passageways had not been assessed. We found eight hundred feet more land in that block than had been assessed. At one hundred dollars a foot, that was eighty thousand dollars' value, which would have meant perhaps, at the rate of taxation at the time, fifteen or sixteen hundred dollars a year loss in taxes. Some people have thought that enough such land would be found in Boston to pay for a complete survey. I do not agree with them, because I think that while there would be places where there might be a considerable amount found in excess of what is being taxed, I know that in many cases more land is taxed than exists. I think probably in a survey of our business district there would be discovered more land than is being taxed, but not enough to pay for the survey. But I would not depreciate the value of a survey on that account. I think it is only due to the assessors of any city that the city should give them an accurate plan on which to work and not expect them to pick up here and there the information that is necessary in order for them to do such important work as the assessing in a large city involves. Some years ago we discovered a case

where the city owned a small piece of land on Washington Street, in the Northampton Street district. We had to raise the grade for sanitary reasons, and the land was all surveyed with the idea that the city might later take it over and reconvey it. At that time the Metropolitan Railway Company had a car stable on Washington Street just beyond Lenox Street. It was formerly city land, as was all the land up in that region. We found in the survey that under that car stable was a strip of land ten feet wide and one hundred feet deep which the city had never conveyed but over which the Metropolitan Railway had built this stable and had continued the use of that land for nineteen years. It so happened that the twenty years which would prevent the city from dispossessing them had nearly expired, so the railway company was notified that the city owned a piece of land there, and they were asked to come around and settle. The firm which represented the Metropolitan Railway at that time was Gaston, Field and Jewell. Mr. Jewell came into our office very much incensed that anybody should accuse his firm, and especially his client, of having stolen any land. We gave him our reasons for claiming the land belonged to the city, with the result that he came around again some time afterward with a check for one thousand dollars. The city accepted that, and gave the company a title to the property. When the South Station was built, a large part of the property on which it was located was docks and wharves. There was a large excess down there which had escaped taxation — I presume partly on account of being dock property not having been considered especially valuable. The largest error that I know of, so far as the number of square feet is concerned, was a case out in Brighton. When Brighton was annexed to Boston it was largely a farming community. There was a piece of land, about six or seven acres, situated on the corner of Brighton and Harvard avenues, belonging to the Herrick estate. It turned out, when the land was surveyed after it came over into Boston, that there was a discrepancy of over ninety thousand feet of land, — over two acres. For the reasons I have mentioned there seem to have been a great many errors, and my appeal to-night is that the assessors of Boston and the assessors of every

TABLE 1. — DETAILS OF SOME CASES INVESTIGATED BY THE STREET LAYING-OUT DEPARTMENT OF THE CITY OF BOSTON WHERE ACTUAL SURVEYS SHOWED AREAS IN EXCESS OF THOSE USED BY THE ASSESSORS.

Location.	Year.	Assessor's Square Ft.	Survey Square Ft.	Excess Square Ft.
Commonwealth Ave., Brighton, Ebenezer Francis Estate	1897	150 000	155 089	5 089
Commonwealth Ave. and Brighton Ave., Ebenezer Francis Estate	1897	174 014	182 179	8 165
Brighton Ave., corner Harvard Ave., Emily Herrick	1897	135 418	227 000	91 582
Brighton Ave. and Linden St., Isaac Pratt Estate	1897	5 286	6 063	777
Cambridge St., Bowdoin Sq. and Green St., Nos. 28 and 30	1898	16 050	18 880	2 830
Green St., Nos. 28 and 30	1898	2 700	3 300	600
Staniford Place	1898	800	1 217½	417½
Brighton St., Nos. 111 and 113	1898	2 400	2 700	300
North St., corner Cross St.	1898	1 700	2 450	750
Medford St., corner Short St., Charlestown	1898	2 500	3 821	1 321
Federal St., Hobbs Wharf	1898	78 515	83 470	4 955
Federal St., Wales Wharf	1898	67 097	70 650	3 533
Federal St., Francis Wharf	1898	91 702	93 546	1 844
Federal St., Curtis and Drake's Wharf	1898	195 260	201 835	6 575
Federal St., Piper's Wharf	1898	75 008	75 689	681
Federal St., Richardson's Wharf	1898	119 383	134 133	14 753
Atlantic Ave., Nos. 183–197	1910	11 352	13 334	1 982
Norfolk St., Dorchester, Sophia L. Door	1912	253 473	272 015	18 542
Monument Sq., Charlestown, estate of Patrick O'Riorden	1912	*	†1 600	1 600
Summer St., corner High St., Moses Williams et al.	1913	2 837	3 051	684
Washington, Avon, Chauncy and Summer Sts.	1914	‡	‡	811
Tremont and Hollis Sts.	1914	‡	‡	1 379
Hawley Place, near Arch St.	1917	1 670	2 735	1 065

* Not assessed. † Approximately. ‡ Total figures not given.

city in New England have placed at their disposal a correct map of the territory which they are to assess, if it is to be assessed by the square foot. The latest case brought to our attention was one of a passageway on a semi-private street, where there was a piece of property which was rather under-assessed, and the amount that it was really under-assessed was really in the passageway, and there was a good deal said about it in the papers; but I think it is a good deal of a question whether it should have been assessed or not. At any rate, it was not, although the Finance Commission and the newspapers talked about it and the counsel for the property said it did not make any difference how much the block contained, as the property was worth so much, and if you called it worth forty thousand dollars and there were three thousand square feet in it, it did not make any difference whether the property was assessed in regard to the passageway or not. But it seems to me it is a good plan to have a correct plan and give all the details that are necessary, and if we are going to tax by the square foot let us know how many square feet we have to tax.

Table I gives the details of some of the many cases which have been investigated by our department.

E. O. Christiansen.* — The important consideration which I would like to emphasize in this discussion of the Cambridge System for the assessment of real estate, is the futility of attempting equitable taxation without equitable assessment, and as a corollary the impossibility of equitable assessment unless based on the foundation of an orderly scientific plan. The necessity for a fair apportionment in the burden of taxation is becoming more and more evident with the increase in the cost of government and the consequent necessity for raising the rates of taxation. The difficulties pointed out in the discussions by Mr. Fales and Mr. Whitney, which confront the assessors working under the rule of thumb methods, make it practically out of the question for them to place just and fair values on property. In other words, if an assessment system is dependent on a matter of personnel, or if the system was developed to suit conditions which no longer exist, the result is invariably evasion or the shifting of the tax burden.

* Formerly Engineer for the Tax Committee of Cambridge, Mass.

At best, individual judgment is a dangerous basis of valuation, and, under a system which allows such rough guess or calculation, it is impossible to avoid error in particular cases. The results of such methods are "liberal" assessments and dissatisfied tax payers. Careful investigations have shown that the large majority of errors in valuation are made to the disadvantage of the city treasury. It has been proven, in every instance where a scientific plan of assessment has been introduced, that the undesirable features of the rule of thumb methods disappear. The scientific plan must of course be adjusted to local conditions.

There are certain advantages of vital importance which accrue from the use of a scientific plan. In the first place, the values which result from its use are not haphazard, but are based on definite and constant economic laws. It also gives the board of assessors an opportunity to obtain a general or bird's-eye view of the city as a whole, and enables them to see clearly relative values of land in various sections and determine the relative values of various types of structures. It does away, to a large extent, with the human equation in the value of real estate. It furnishes a common language for discussion between the tax payer and the assessors. The plan also makes it possible for the board of assessors to convince the tax payer that he is being fairly treated and that he is only paying his relative proportion of the taxes. For this reason particularly, such a plan will satisfy business interests in the community in that all a business man wishes to be guaranteed is that his property is taxed no more than others of a like nature. Lastly, the system also provides for a constant flow of information into the assessor's office by means of which the department is in a position to follow closely the changes in developments of the various sections of the city. Coupled with close coöperation between the assessors and other departments of the city government, publicity and businesslike methods, such a plan should eliminate most of the difficulties which we are laboring under with the present unscientific and troublesome method of real estate valuation for tax purposes.

Mr. Bell.*— The question has been asked concerning the application of our system to a street like State Street in Boston,

* Author's closure.

between Washington Street and Merchants Row, where every lot is of a different size and shape.

It would be a very simple matter to place a unit on State Street. Take a specimen block of the city of Cambridge. There are no two lots in the block that are the same. The unit on this street is 30 cents. One lot is 100 ft. deep and 50 ft. wide, — and with a 30-cent value $1 500 is its value. Another lot is 113 ft. deep and 55 ft. wide. Apply this same unit and its value is $1 753. The fact that the lots are irregular makes no difference in the valuation of the unit. That is merely for the basis of the assessment. It does not make any difference what sort of development you have, speaking broadly, provided it has the average development of the district. There is no especial consideration to be given for development, as to the value of the unit on that street. In other words, you neglect your lot lines. You fix your unit on the value of one square foot on the street. Then given this, you apply it to the area of the particular lot and get the value of the lot. It sounds complicated, but if you think of it in a perfectly regular lot such as one 100 ft. deep by 50 ft. wide, and 30 cents to the unit, it is perfectly easy to see that the total value is $1 500.

One of the simplest things in the whole system is the application of the plan to irregular lots. It is perfectly easy, once you have the tables laid out, to apply them to lots of any shape; and further than that, as Mr. Fales has just suggested, that is where the application of a plan of this sort gives a good deal more certainty to assessments than does the rule of thumb that the assessors have been using in New England. There is no question but what property which is assessed under a system gets a good deal fairer treatment at the hands of the assessors than does property where the assessor goes in and says he thinks the land is worth so much money. The owner says it is worth a different amount. They do not get together because it is merely an expression of opinion on one side as opposed to an expression of opinion on the other side. In this case the individual citizen may apply these rules to his own particular lot, and may see whether they are properly plotted. He may see whether the proper coefficient is obtained, and if not have it

corrected, and then, having established the fact that he has, he may apply that to his lot. If he has anything to say with regard to how that is worked out he can talk it over with the assessors and point out perhaps that it is founded on a wrong curve, just as the real estate men in Cambridge demonstrated to us.

The original induction of this system cost about $11 000 in addition to what was paid the assessors.

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BOSTON SOCIETY OF CIVIL ENGINEERS
FOUNDED 1848

PAPERS AND DISCUSSIONS

NEWTON, MASS., WATER-WORKS RESERVOIR.

By Edwin H. Rogers,* Member Boston Society of Civil Engineers.

The covered water-works reservoir of the Newton water-supply system, as designed by the city engineering department of Newton and constructed under its supervision, is now completed and comprises four rectangular sections with a circular gate chamber at the center, in which are installed a steel distributing tank and pipes from the force main to the different sections and the overflow pipes and drains for emptying the several sections.

Section 1 is the southeasterly section, and was built in 1890; Section 2, the southwesterly section, built in 1901; and Sections 3 and 4 the northwesterly and northeasterly sections respectively, built in 1916 and 1917.

The dimensions of the different sections vary from 127 ft. in width to 174 ft. and 165 ft. in length for Sections 1 and 2, to 129 ft. in width by 214 ft. and 206 ft. in length for Sections 3 and 4. The full depth of water is 15 ft., and at this depth the total capacity of the four sections is about 10 400 000 gals., the different sections containing from about 2 200 000 gals. to 3 000 000 gals. each.

Note. This paper will not be presented at a meeting of the Society, but discussion is invited, to be received by W. L. Butcher, Editor, 715 Tremont Temple, Boston, before November 10, for publication in a subsequent issue of the Journal.

* City Engineer, Newton, Mass.

The type of construction of Sections 1 and 2 is nearly similar, whereas the design adopted for Sections 3 and 4 is radically different. Sections 1 and 2 are built with random rubble masonry gravity walls, extending some three feet below the floor of the reservoir, the roof of these sections being supported by brick columns on rubble masonry foundations below the floor. The roof of Section 1 consists of cylindrical arches supported by other arches at right angles, springing from column to column, and the roof of Section 2 is reinforced concrete flat slab construction supported by longitudinal steel I-beams. All of the sections have the roof covered with loam from 18 ins. to 2 ft. in thickness.

Description of Sections 3 and 4.

Sections 3 and 4 (Fig. 1.) are built of concrete throughout, the exterior and dividing walls being 2 ft. to $2\frac{1}{2}$ ft. thick at the top and 4 ft. thick at the bottom, and the walls as well as the columns are constructed on and rest directly on the floor, which is a concrete slab 12 ins. thick under the walls and a short distance inside, and 8 ins. thick under the rest of the structure. The exterior walls are reinforced by $\frac{3}{4}$-in. square bars 18 ins. on centers, so as to act as beams to resist the earth pressure of the embankments, the overturning moment being resisted by the roof, and the floor under the walls is reinforced at the corners. The dividing wall between the two sections is reinforced on each side by $\frac{3}{4}$-in. square bars placed 12 ins. on centers to resist the bending moment caused by water pressure when one of the sections is full and the other is empty, the wall being prevented from overturning by the roof acting as a strut. The wall reinforcement extends slightly into the haunches of the roof arches. The floor under the columns is reinforced by a grillage of $\frac{3}{4}$-in. square bars, thus distributing the load on the columns in such a manner as not to exceed a suitable pressure per square foot on the supporting soil. The floor was further reinforced by 6-in. by 6-in. galvanized Clinton wire cloth, lapped at all joints, to distribute temperature stresses occasioned during construction. The floor is level, at grade 305.27, Boston City Base. The floor is depressed longitudinally through the center bays in each

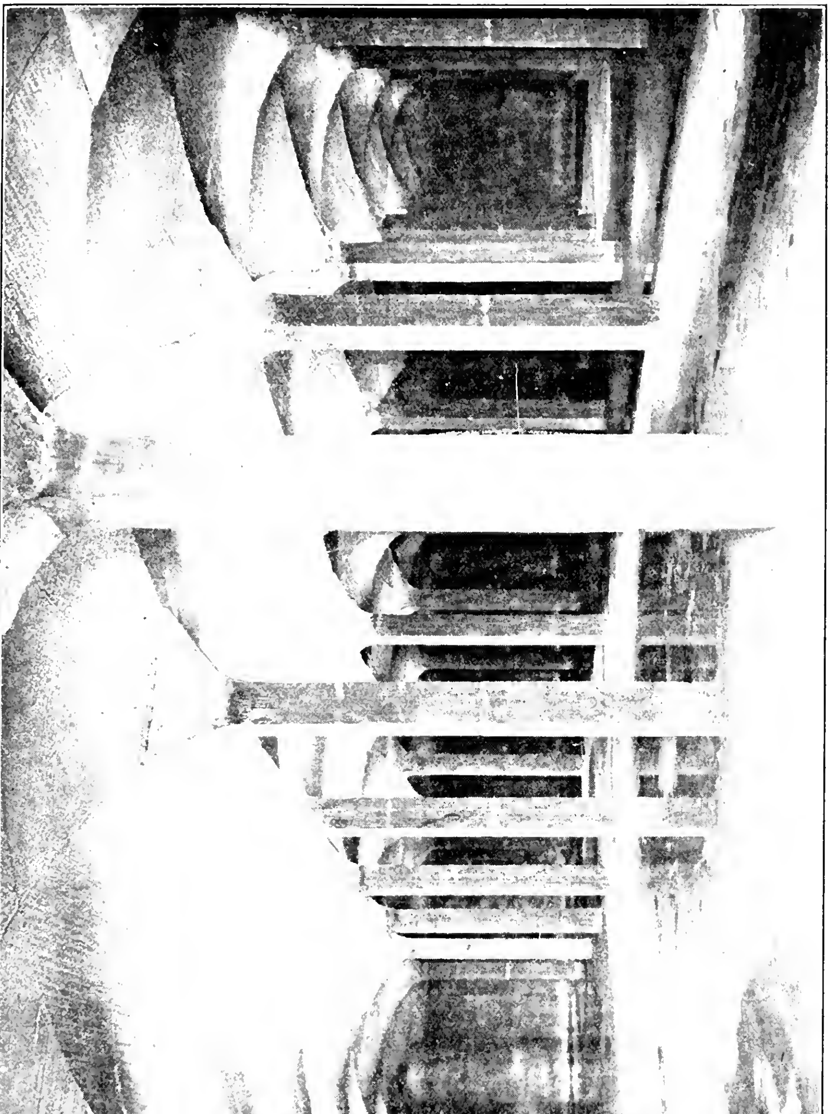

FIG. 1. WABAN HILL COVERED RESERVOIR. Interior of Section 4.

section, so as to form a gutter 2 ft. wide at its invert, with sloping sides and having a pitch of about 5 ins. per 100 ft. to the drainage outlet pipes. These gutters are to assist in cleaning the reservoir as required.

The roof (Fig. 2 and Fig. 3) is of groined arch construction without reinforcement, the intrados being semi-elliptic with a rise of 3 ft., the extrados being parabolic with a drop of 9 ins. over the columns, the thickness of the arch at the crown being 6 ins. The span of the arches is 13 ft. 1 in. in each direction.

The 16-in. by 16-in. concrete columns are without reinforcement except for $\frac{3}{4}$-in. dowels at their bases, connecting them to the floor, and $\frac{5}{8}$-in. pintles at their tops running into the haunches of the arches, and are spaced 14 ft. 5 ins. on centers each way.

The walls are reinforced longitudinally sufficiently to prevent cracking between the expansion joints, which were inserted at intervals of from 30 ft. to 35 ft. These expansion joints are provided with a folded sheet-lead dam to prevent leakage, and a sheet-steel dam is provided between walls and the floor for the same purpose.

Circular cast-iron ventilators 18 ins. in diameter and extending 12 ins. above the loam surface, with narrow slits in their sides, are provided in the roof, and one cast-iron manhole in each section provides access for inspection and cleaning.

The 24-in. cast-iron inlet pipes enter the sections from the central gate chamber at the flow line, continue of cast iron on a 45-degree slant to the floor, and are extended along the floor of vitrified pipe construction embedded solidly in a concrete base. The flow line is at grade 320.27.

The 24-in. outlet pipes are beneath the floor and located close to the central gate chamber. The drainage pipes to be used in cleaning the reservoir are 12 ins. in diameter.

The sections are covered with filling and loam 18 ins. in thickness over the crowns of the arches, and embankments on a 2 to 1 slope are built adjoining the outside walls and covered with 12 ins. of loam. The excavation for the site of these sections was done largely with a steam shovel and horse-drawn dump carts, the material excavated from the site providing the greater

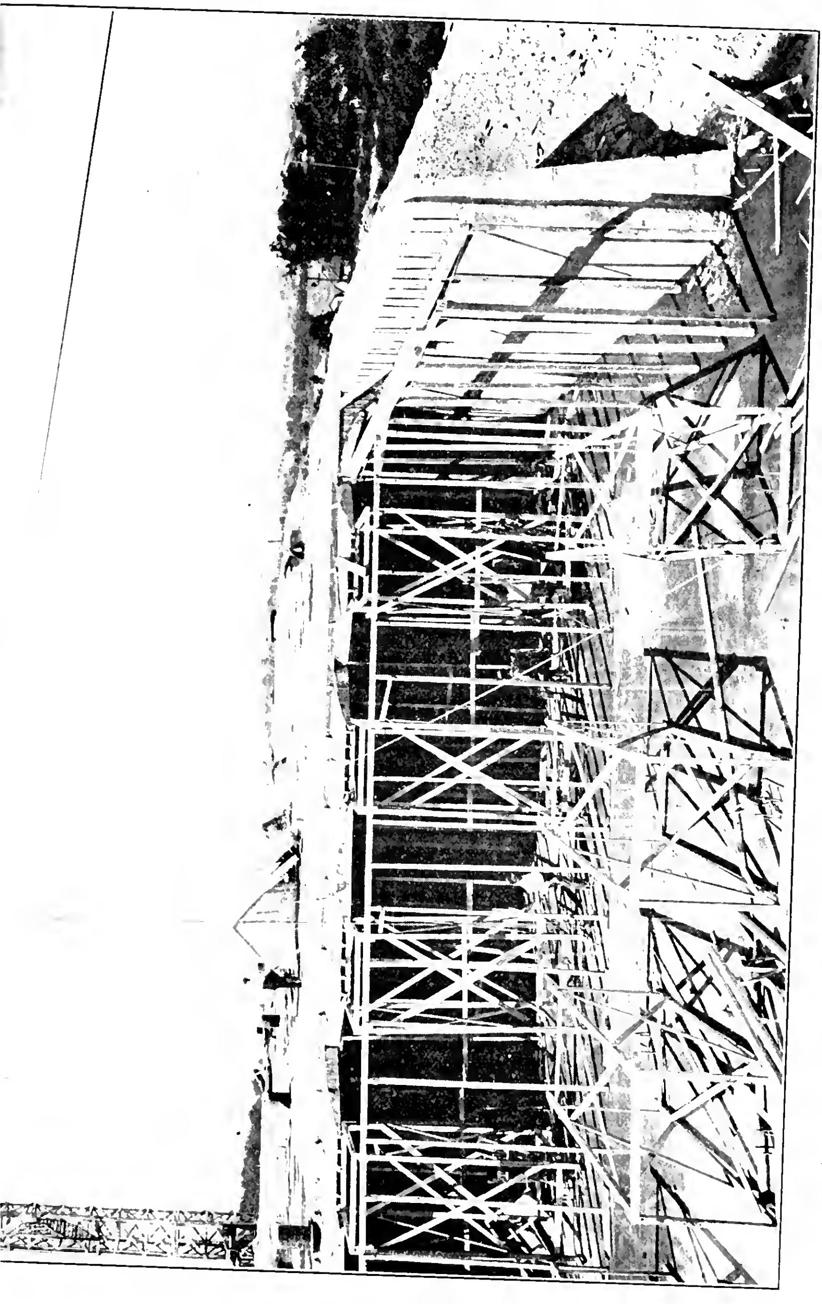

FIG. 2. WABAN HILL COVERED RESERVOIR. June 28, 1917. Roof 60% completed on Section 4.

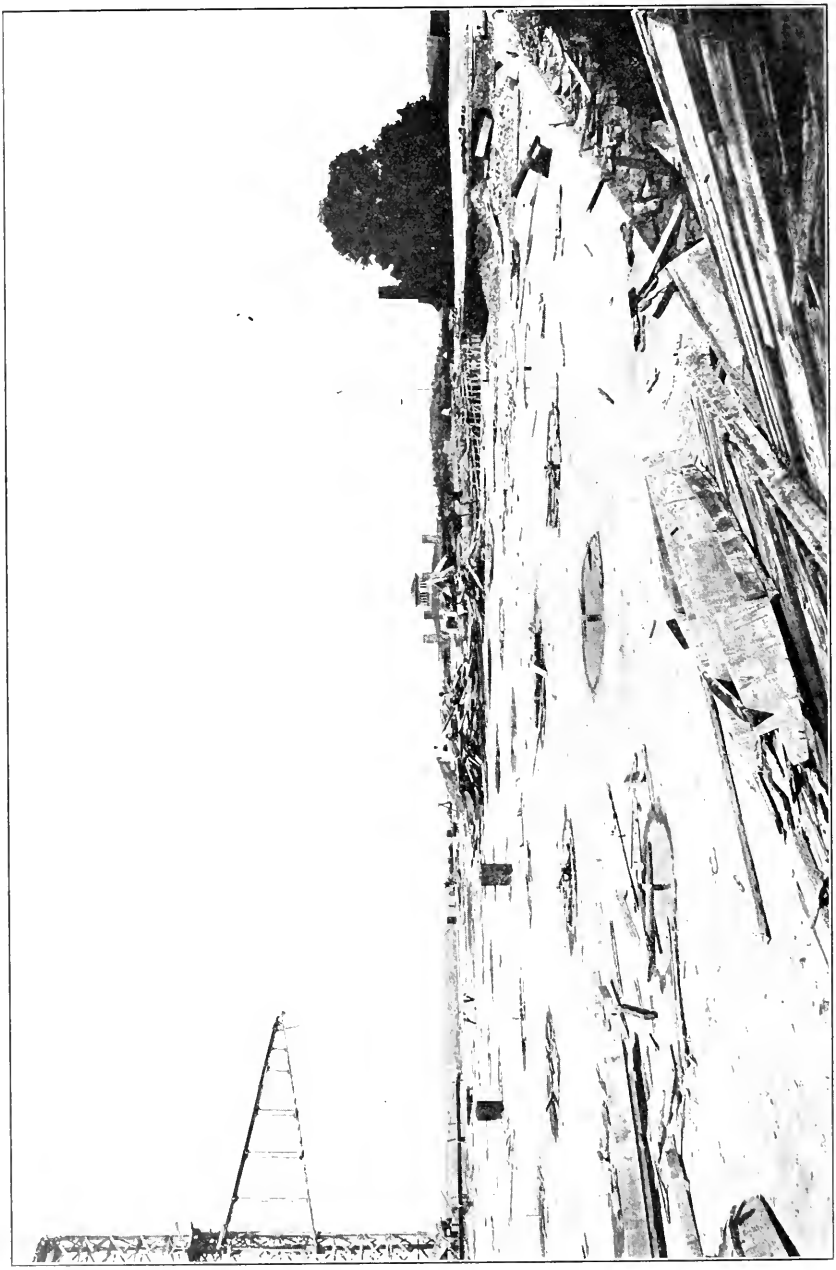

Fig. 3. Waban Hill Covered Reservoir. June 28, 1917. Roof completed on Section 3, and partly done on Section 4.

portion of the filling and loam required. The material on which the reservoir is constructed consists of what is locally known as hardpan, i. e., an intimate mixture of clay and gravel, muddy when wet but hard and dense when dry, and of such a nature as to provide an excellent foundation.

The construction plant consisted of a wooden tower over 100 ft. in height, erected on the northerly side of Sections 3 and 4, opposite the retaining wall between them, with the concrete mixer at its base and bins for the storage of the sand and stone on the northerly side of Section 3, whence the aggregate was conveyed to the mixer by an industrial railway operated by a cable from the stationary engine which furnished power for the mixer and the elevator in the tower. Chutes from the tower in several sections were provided of lengths sufficient to reach to any part of the work and were used for placing most of the floor and walls. These chutes were difficult of operation unless a large percentage of water was used in the concrete, and so their use was abandoned for the placing of the columns and roof work, in which a drier mixture of concrete was advisable than used in the floor and walls.

The concrete for the columns and roof was dumped from the tower directly into steel concrete barrows or buggies and pushed by the workmen where required.

Wooden forms were used for the walls, steel forms for the columns and the capitals of the columns part way up the arches, and wooden forms for the balance of the groined arches, the latter forms being supported by wooden posts from the floor. The steel forms proved very suitable for the straight portion of the columns, but the flaring portion of the steel forms was not all that could be desired, as they were designed without sufficient stiffening and bulged with the weight of the concrete. This bulging and the difficulty of making a smooth joint at the junction of these steel forms with the wooden forms forming the balance of the arch caused the arches to be more or less irregular, and while the strength was sufficient the effect was a lack of symmetry.

Crushed stone was used for the coarse aggregate in the concrete, and the sand and cement were frequently tested and

found to meet the specifications of standard requirements in each instance.

The floor was finished by the use of a roller made of a 3-in. pipe, a method which has since been adopted in many instances for the finishing of concrete roads. The walls and columns were washed with grout after the forms were removed.

The Newton water supply is obtained from underground sources, and the temperature of the water only varies some 10 degrees Fahr. during the year. A covered reservoir containing such water is therefore subjected to but slight temperature stresses, and the structure was designed with the expectation that the whole work would be completed and filled with water during one season, thus doing away with the necessity for more than a minimum allowance for expansion and contraction during construction. The work was started so late in the season of 1916 that only the greater part of the floor area and walls were completed. The reinforcement in the floor, however, distributed the contraction stresses so that only hair cracks were apparent in the winter time, and the expansion joints provided in the walls proved adequate. It was noted that some of these latter joints did not open at all, and others a substantial amount during the cold weather.

The reservoir was completed during the autumn of 1917, but the water was not admitted during the winter as the controlling gates have not yet been placed in the gate chamber. This past winter was of unusual severity, the thermometer on occasions registering below zero for several days at a time, but it was observed that the temperature of the air in the interior of the empty sections did not fall below 33 degrees Fahr., and although the loam filling and the groined arch roof were frozen solid, as evidenced by the frost adhering to the under side of the arches, yet no cracks were apparent in the concrete of the roof, the only effect being that the construction joints along the crown of the arches opened up sufficiently to indicate their location, but without apparent impairment of the stability of the roof.

MEMOIRS OF DECEASED MEMBERS.

ELMER LAWRENCE CORTHELL.*

BORN AT SOUTH ABINGTON, MASS., IN 1840.
DIED AT ALBANY, N. Y., MAY 16, 1916.

MR. CORTHELL entered Brown University, but after two years the Civil War broke out and he enlisted in the First Regiment, Rhode Island Light Artillery. He advanced from private to captain, and saw active service for four years in Virginia and North Carolina. After the war he resumed his college course and was graduated in 1867, receiving the degree of bachelor of arts. In the following year he received the degree of master of arts, and in 1894 the degree of doctor of science, both from his alma mater. He attained high rank in college, and achieved membership in the Phi Beta Kappa, an enviable distinction.

Upon graduating in 1867, he entered the office of Cushing & DeWitt, civil engineers in Providence, and engaged in general engineering practice. The following year he became assistant engineer on the Hannibal & Naples Railroad in Illinois, and in 1869 he had charge of location and construction of forty-five miles of the Hannibal & Central Missouri Railroad. In 1870 he became chief assistant engineer in the construction of the bridge over the Mississippi River at Hannibal, Mo., and from 1871 to 1874 he was chief engineer of the Sny Island Levee, fifty-one miles long, on the east bank of the Mississippi River. In 1873–74 he was also chief engineer for the bridge over the Mississippi River at Louisiana, Mo., for the Chicago & Alton Railway.

In 1874 he began his association with Mr. James B. Eads, who at that time was asking Congress to give him a contract for improving the mouth of the southwest pass of the Mississippi River by means of jetties. After the contract had been

* Memoir prepared by George F. Swain.

obtained, Mr. Corthell was invited to take charge of the engineering construction work and he was engaged upon this until 1880. This work resulted, as is well known, in increasing the depth of the channel from nine feet to over thirty feet, and in a vast increase in the commercial importance of the port of New Orleans.

In 1879–80 Mr. Corthell published an illustrated history of this undertaking. This work, in which Mr. Corthell showed remarkable skill, energy and resourcefulness, was the beginning of a long series of important works connected with the improvement of rivers and harbors in this and in foreign countries. Indeed, Mr. Corthell's principal life work may be said to have been in this branch of engineering, although he did much in other lines, and from 1881 to 1884 was chief engineer on the construction of the New York, West Shore & Buffalo Railroad and the New York, Ontario & Western Railway.

In 1880 Mr. Corthell went to the isthmus of Tehuantepec, Mexico, for Mr. Eads, to make surveys for the proposed ship railway, by which loaded vessels were to be carried bodily on rails across the isthmus in a cradle. From 1885 to 1887 he gave almost his entire attention to this project, and many engineers will remember the interesting model which he exhibited all over the country, illustrating the engineering details by which this novel enterprise was to be carried out. While the enterprise itself came to naught, the work of Mr. Corthell was of value in calling attention to the commercial aspect of the inter-oceanic canal projects.

In 1887 Mr. Corthell became associated with Mr. George S. Morrison in a partnership, in the course of which he had to do with the construction of important bridges over the Ohio and Missouri rivers. He also had to do with water works at Bismarck, Dak., with the construction of belt railroads at Chicago, and other works.

After 1888 Mr. Corthell continued his practice as a consulting engineer with offices in Chicago and New York, and his activity led him to become connected with many important works, among which may be mentioned the St. Louis bridge over the Mississippi River, the improvements at the mouth of the

Brazos River, Texas, railroad terminals at Chicago and New Orleans, the harbor at Tampico, Mexico, the Tehuantepec National Railroad, the improvement of harbors in the Argentine Republic and in Brazil, the barge canals for the state of New York, and other works too numerous to mention.

Mr. Corthell's engineering activity led him to give a great deal of attention to the study of questions of commerce and navigation, both from an engineering and a commercial point of view. He examined many harbors in Europe in connection with his work at Tampico and elsewhere, and he was very active in the international engineering congresses, being vice-president of the Seventh Congress, held at Brussels in 1898. Probably it is not too much to say that his acquaintance among foreign engineers was greater than that of any other American engineer. To the proceedings of engineering societies and congresses he contributed many important papers.

Mr. Corthell was also interested in engineering education. As a trustee of the University of Chicago he examined the leading technical schools of Europe to obtain information to aid the university. He was loyal to his alma mater, and left to that institution his valuable collection of books, pamphlets and reports.

Mr. Corthell was also deeply interested in the various engineering congresses which have been held, and gave time and effort to making them successful. He was active in connection with the Chicago Exposition, and by his engineering suggestions and plans did much to make it a success. He was chairman of the general committee of the engineering congress held at that time, the valuable results of which are comprised in a number of volumes of papers and documents by leading engineers from all parts of the world and in all branches of engineering. He was also vice-chairman of the international water commerce congress held at the same time.

Space will not permit of further notice of the numerous works and activities of Mr. Corthell, but it will be evident from what has been stated that he was one of the leading engineers of the country and that his energy seemed unlimited. He was always doing something, proposing something, accomplishing

something, and spurring others on to emulate him. His success met with wide recognition. His advice was widely sought, his judgment universally respected, and he received many honors from scientific societies, governments, governmental departments and institutions of learning. The closing honor which came to him was his election as president of the American Society of Civil Engineers in 1916. While he, unfortunately, did not live to complete his term of office, it was a great satisfaction to his many friends to feel that this honor had been conferred upon him, and he himself appreciated it to its full extent.

Mr. Corthell made hosts of friends. He was always thoughtful and encouraging in his dealings with younger engineers; he was a man of the most kindly disposition and the widest sympathy, and his indefatigable industry and unwearied activity, which continued up to the day of his death, were an inspiration to all who knew him. He will not soon be forgotten by those who had the privilege of knowing him; and to know him was to love him.

JOHN WALDO ELLIS.*

Died October 30, 1916.

John Waldo Ellis was born in Woonsocket, R. I., on September 7, 1845, and finished his school education at New Hampton Institute, New Hampton, N. H. At the age of nineteen he entered the engineering force of the Boston, Hartford & Erie Railroad, then under construction from Waterbury, Conn., to Fishkill, N. Y. He afterwards was made division engineer of the Troy & Greenfield Railroad before the completion of the Hoosac Tunnel. From this road he went to the Norwich & Worcester Railroad, then building, and in 1869 came to Woonsocket, R. I., as chief engineer of the Providence & Worcester Railroad, at the same time opening an office for private practice in that place, which he maintained up to within a few years of his death.

Mr. Ellis held the position of chief engineer of the Providence & Worcester Railroad, up to the time that road was ab-

* Memoir prepared by J. Parker Snow, who states that he has taken his facts largely from the able memoir of Mr. Ellis by Lester W. Tucker, Proceedings, American Society of Civil Engineers, March, 1917, page 512.

sorbed by the New York, Providence & Boston Railroad in 1888. Under his direction the road was double-tracked, many branch lines were constructed, the Wilkes-Barre Coal Pier and connection was constructed at Providence, and many bridges, stations and other structures were rebuilt. During this same period Mr. Ellis's private practice in Woonsocket was at its height, and many prominent engineers of the present day received their first experience in the old Main Street office. The design and direction of the construction of Nourse Mill of the Social Manufacturing Company, the Alice Mill of the Woonsocket Rubber Company, and numerous other industrial plants and enlargements in northern Rhode Island, were a part of the activities of his office.

From 1890 to the time of his death, Mr. Ellis was connected prominently with various engineering problems in New England. He was engineer for the Old Colony Railroad Company in the building of the Providence passenger terminal, and engineer inspector of the Boston & Providence Railroad from the time of its lease to the Old Colony Railroad until his death. His connection with various grade-crossing matters in Massachusetts and Rhode Island included many of the important problems in that line. He was one of the commissioners for the elimination of grade crossings in Lowell, in Athol and in Orange, Mass., and was employed as engineering expert by the cities of Lynn, Worcester, Cambridge, Fall River, Taunton, Haverhill, Readville and a large number of other towns.

As a water-works expert, Mr. Ellis was among the foremost in New England, serving as one of the commissioners in the valuation of the Newburyport and of Gloucester water works when these were taken over by these cities. He was also a member of the commissions in the diversion claims against the city of Pittsfield and the claim of the Nassau Paper Company against the Metropolitan Water Board.

As a town and city engineer, Mr. Ellis was especially active, serving as town engineer of Woonsocket from 1870 to the time it became a city in 1888. He also served as engineer for the town of Blackstone, and for other surrounding towns, up to the time of the closing out of his private practice.

As a hydraulic engineer, Mr. Ellis was very active, and the Blackstone and other rivers in Massachusetts and Rhode Island have many dams constructed under his direction. The most prominent of these are the Lonsdale, Ashton and Wilkinsonville dams on the Blackstone; the Slatersville Reservoir Dam and Middle Dam on the Branch River, and the Georgiaville Dam on the Woonasquatucket, in Rhode Island.

He was elected a director of the Providence Gas Company on February 26, 1900. This followed the successful completion under his engineering supervision of the difficult and important work of laying a submarine pipe across a narrow arm of the bay, from Providence to East Providence. He was elected president and general manager of the company on March 4, 1901, and discharged the duties of this office for more than fifteen years and until his death. During this time large extensions of the plant were made, including the first installation of Dessau vertical retorts in America.

Notwithstanding his many engineering engagements and business connections, Mr. Ellis found time to be a most efficient director and manager in other fields. He was a member of the board of directors of the Industrial Trust Company of Providence, and chairman of the board of the Woonsocket branch of that Company. He was a director in the Woonsocket Rubber Company and many other corporations. He was also a trustee of the Woonsocket Institution for Savings, from 1876 to 1908, and a trustee of the Woonsocket hospital from its founding in 1890 to the time of his death. Although a prominent member of many clubs and social organizations, Mr. Ellis had no connection with any fraternal or secret orders. He was a member of the American Society of Civil Engineers and served as a director from 1904 to 1906 inclusive. He was also a member of the New England Water Works Association.

His principal diversion in his leisure was that of driving. From the time when he established his home in Woonsocket his stable always contained at least one good, blooded trotting horse, and, when the roads were good or the sleighing at its best, Mr. Ellis was to be seen among the fastest of those on the speedways. He was a member of the Woonsocket Driving Club,

the Roger Williams Driving Club of Providence, and the Metropolitan Driving Club of Boston, and it is interesting to note that only three weeks before his death he drove on the track of the latter club.

Mr. Ellis was a prominent figure in the political field of Woonsocket for many years. He served as alderman from his ward, and was president of the board during this service. In 1904 he was elected state senator from his city and served on many important committees.

He was a member of the board of trustees of the First Universalist Church for many years.

Mr. Ellis was a man of marked ability and superb courage, and was recognized as a leader in any activity into which he entered. His business ability, keen foresight and tremendous energy, his unimpeachable integrity, faithful attention to duty and resourcefulness in difficulties, made him a most valuable adviser and representative in engineering, civic and social lines. His wide acquaintance among prominent men gave opportunities for the exercise of these attributes to a remarkable extent. It is seldom that work of such varied character is executed with such invariable success as attended the career of Mr. Ellis. The scope of his talents was wide, and indicated a breadth of mentality seldom found in one man.

Mr. Ellis was married, on May 23, 1870, to Mary F. Howe, who, with one son and two daughters, survives him.

He was elected a member of the Boston Society of Civil Engineers on May 19, 1896, and served as President for one year from March 15, 1905.

FRANKLIN BUCHANAN LOCKE.*

Born at Hampton, N. H., February 23, 1857.
Died May 11, 1917.

Franklin B. Locke came of New England ancestry, and was well known for many years in New England as a capable and resourceful engineer. He was a lineal descendant of Capt. John Locke, who is described as a man of prominent position

* Memoir prepared by George F. Swain.

among the early settlers of New Hampshire, and was finally killed by the Indians in 1696.

He received his engineering education at the Massachusetts Institute of Technology, where he was a member of the class of 1877, but discontinued his course after three years to engage in the work of construction of the Hoosac Tunnel. His elder brother, Augustus W. Locke, also an eminent engineer, was engaged upon the same work, and after the completion of the tunnel became superintendent of the Troy & Greenfield road. Frank was assistant engineer on the tunnel until 1881, when he formed a partnership with his brother, and the firm became known as perhaps the leading engineering firm of western Massachusetts.

His work was of great variety, covering the fields of railroad engineering, municipal engineering, and even mining engineering. One of his earliest engagements was as engineer for the extension of the water-works and drainage system of North Adams, Mass. He also had charge of the double-tracking of the state road east of the tunnel and of the masonry. In 1881–82 he was a principal assistant engineer on the Buffalo, Rochester & Pittsburg Railway on that portion of the line between Salamanca, N. Y., and Ridgway, Pa. He did some valuable and interesting location work on the Mountain Division south of Bradford, Pa., through a country parallel to the line of the Erie Railroad over the Kinzua Viaduct. He resigned this work owing to poor health, and spent a time traveling in Europe, visiting most of the great Alpine tunnels and inspecting European railways. Returning to this country, he was engineer of maintenance of way of the Troy & Greenfield Railroad, which embraces the Hoosac Tunnel. He was also chief engineer of the Hoosac Valley Electric Railroad, which runs through Adams, North Adams and Williamstown, and of a branch of the Fitchburg Railroad, which he constructed. He also investigated and reported upon numerous railroad and mining properties in the west, and for a time was engineer for the Michigan Hydraulic Mining Company in Idaho, and also for some mines in Utah. In connection with his brother he became greatly interested in the problem of abolishing railroad grade-crossings in Massachusetts, and was connected with projects for several works of this kind.

Finally settling in North Adams, Mass., he held the office of city engineer for a number of terms, and also the office of commissioner of public works. Indeed, for many years he was depended upon to take the lead in the engineering work of the city of North Adams. While in these positions he had to do with the construction of water works, sewers, roads and bridges. He built many roads, and was an authority on their construction. He was, probably more than any one else, responsible for the successful recent extension of the North Adams water works, which he planned and began.

One of Mr. Locke's most recent activities was in connection with the location and construction of the so-called Mohawk Trail, a state road across the Berkshire Hills between North Adams on the west and the Deerfield Valley on the east. Indeed, he is known in the vicinity of North Adams as " the father of the Mohawk Trail." While he started the movement for this road and surveyed a line, his route was not adopted by the state officials, although many considered it the best line. At any rate, Mr. Locke was the man who first conceived the idea of this trail.

Mr. Locke had traveled much in this country and abroad, had assimilated his experience and had gathered a great deal of knowledge. He had read widely and intelligently. Some people travel and read, but do not learn; but he was not of this sort. His breadth of interest was greater than that of most engineers. He had an artistic nature, and had even given some attention to art. He was modest, retiring, and if he had any fault it was that he did not push himself to the extent that his ability warranted, for he was really a man of fine perception, strong common-sense, and exceedingly capable as an engineer. With greater stimulus he might have made himself better known, and might have achieved a greater measure of what is usually, though probably mistakenly, termed success; but he preferred the quiet retirement of his home and the society of his friends and of his books, and probably after all he derived in that way a greater measure of real satisfaction than falls to the lot of those who are more prominent or pushing in the battle of life. He was sociable, upright, hopeful, courageous, conscientious and

true. He had a high conception of the calling of the engineer, and no one could ever say that he had failed in his duties toward his fellow-men. He made many friends and lost few. He was beloved by all who knew him. His judgment was relied upon by all who had had opportunity to test it, and his death left a gap in the hearts of his friends and in the engineering circles in which he moved which will be indeed difficult to fill. Even after his health became impaired his advice was sought and relied upon. In his home town, where his friends were legion, he will be sadly missed; but as long as a good water supply and the beauties of nature are appreciated his name will be held in affectionate remembrance.

Mr. Locke had been in failing health since 1907. Indeed, he had never been extremely robust. Nevertheless he continued to serve his state to the extent that his strength would permit. In 1914 his health broke down, and he had to give up public responsibility, and resigned as commissioner of publc works. A trip south benefited him for a time, but afforded no permanent relief. He died in a hospital in Boston quite suddenly, when his friends thought he was out of danger.

Mr. Locke was a member of the American Society of Civil Engineers which he joined March 1, 1893, and also of the Boston Society of Civil Engineers, the American Institute of Mining Engineers, the North Adams Club and the Berkshire Club.

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BOSTON SOCIETY OF CIVIL ENGINEERS
FOUNDED 1848

PAPERS AND DISCUSSIONS

NOTES ON THE CONSTRUCTION OF THE MYSTIC RIVER BRIDGE, EVERETT EXTENSION OF THE BOSTON ELEVATED RAILWAY COMPANY.

By Clarence T. Fernald,* Member Boston Society of Civil Engineers.

(Presented September 18, 1918.)

History.—The inception of the Everett Extension, so-called, began with the acceptance of Chapter 497 of the Acts of the Legislature for 1907, by the cities of Everett and Malden, and the Boston Elevated Railway Company, in July, 1907.

Not until four additional acts had been passed by the legislatures of 1913, 1915 and 1916, was construction started, and yet again in 1917 still another act was passed relative to the location of a permanent station in Everett.

The intervening time between these dates, or a total of about nine years, was occupied by the Company in making surveys, studies, or holding conferences and trying to satisfy or reconcile the various factions in these two cities as to route, type of construction, location of stations, and obtaining the necessary approvals of governmental boards.

The greatest modification in legislation, however, was made by the passage of Chapter 777 of the Acts of the Legislature for 1913, by which the location for an elevated railway in Everett and Malden north of the Broadway crossing over the Boston &

*Assistant Engineer, Boston Elevated Railway Company, 101 Milk St., Boston, Mass.

Note.—Discussion of this paper is invited, to be received by W. L. Butcher, Editor, before December 10, 1918, for publication in a subsequent issue of the Journal.

Maine Railroad was revoked, and a route for a double-track subway substantially following the line of Main Street was substituted in its place.

It was under this new act that work on the plans for the present bridge began.

The original bridge plans which had received the approval of all the local boards, needing only the sanction of the Secretary of War, and having been contracted for contingent upon the approval of all the public authorities, were abandoned.

By reason of this new act of 1913 the Company found itself with numerous parcels of real estate on its hands, in many instances having razed the old buildings to proceed with the new construction.

Its obligations relative to the Mystic River Bridge, however, were the most onerous, as they involved the following items:

a. The relocation of the channel 334 ft. further north.

b. The construction of a new highway drawbridge.

c. The rebuilding of the pile bridge approaches, and an approach 900 ft. long on filled land.

The type of foundations, length of spans, type of steel structure and details of the drawbridge for the new elevated bridge were entirely changed, and all the approvals had to be again obtained before construction could begin.

The foregoing facts are cited as a concrete instance of the difficulties encountered by public service corporations, who are obliged to proceed in good faith in their contracts with municipalities. These municipalities act on the theory that the power which gives may take away, and as views change with every administration so do the laws regardless of previous obligations. In my humble opinion, some safeguard should be provided to make contracts of this kind as inviolate as are those between commercial houses or corporations, during the term of the contract, i.e., adequate compensation being guaranteed for any change from the original contract.

General Layout of Work.

The plans as finally approved by the several boards (Fig. 1) provided for a bridge or elevated steel structure crossing the

Mystic River from a point on the south shore about 80 ft. west of the highway bridge, and joining the north end of the Beacham Street car yard, to a point near the pumping station of the Metropolitan Sewerage System, a distance of 844 ft ±. From this point the Elevated structure continues for about 2 341 ft., where it reaches the ground and the tracks extending on the surface to

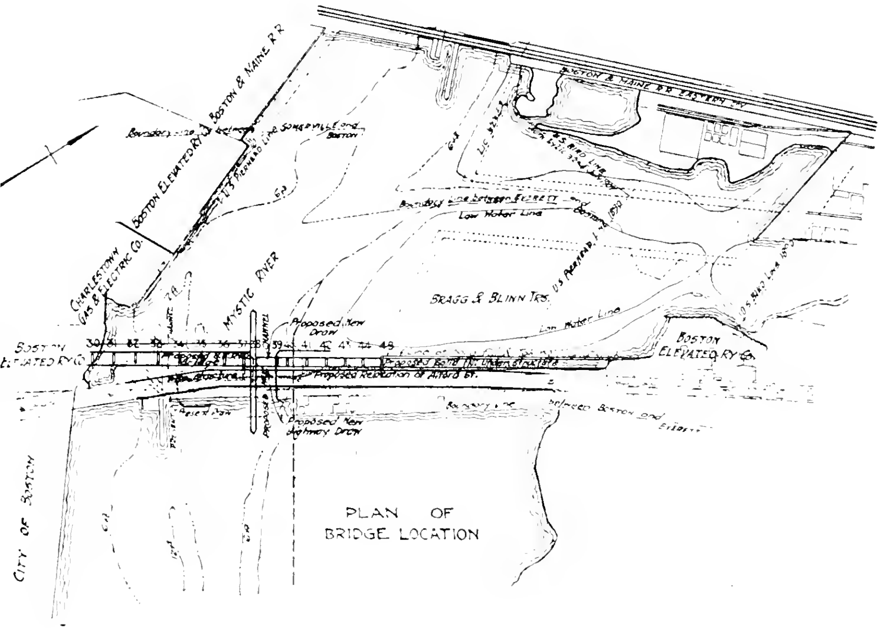

FIG. 1. PLAN OF BRIDGE LOCATION.

the proposed temporary station, a total distance of one mile north of the present Sullivan Square Terminal.

The alignment of the highway bridge was moved westerly about one half its width, to a line parallel to and about 18 ft. away from the Elevated structure. North of the pile bridge the approach included the construction of a heavy sea wall, 300 ft. long, averaging 16 ft. high, and a 4-ft. to 5-ft. fill extending 600 ft. further north.

In each bridge there was located a Strauss bascule drawbridge, providing for a width of 75 ft. clear opening, and a depth of 30 ft. of water.

The railway drawbridge was built at a high level, having from 26 ft. to 28 ft. headroom under it at high water, the counterweights being underhung. The highway drawbridge had a moving leaf, 60 ft. wide and 105 ft. long, and was of the heel trunnion type, i. e., the counterweight was suspended over the roadway, being supported upon upright columns hinged at the rear or heel end of the moving leaf. Both drawbridges were built by the Boston Bridge Works.

Bridge Foundations.

The depth of water at the draw opening was fixed by the War Department at 30 ft., and here the dredging for the channel foundations on either side was carried down to about elevation 68, and the piles were cut at 69.50 in piers 39 and 39E; those in pier 38 were not cut but left at about elevation 71, the plane of reference being 100 ft. below Boston base.

The piles for all the other piers, excepting the two abutments, were cut at grade 80, and the abutments at grade 85.

Design.

The piers for the three-track structure were 44.75 ft. by 17.25 ft., and for the two-track structure north of the draw 34.17 ft. by 16.66 ft. bottom dimensions, the former having 102 piles and the latter 78 piles, averaging 30 ft. long and spaced 2.5 ft. on centers. (See Plates I and II.)

The four large draw piers (see Plates III and IV), viz., Nos. 37, 38, 39 and 39E, varied in size from 124 ft. by 19 ft. to 34.17 ft. by 19.16 ft., and the latter three were carried down to about grade 69.5, as previously noted.

In all cases the concrete, of 1 : 2 : 4 mixture, was carried from the piles to grade 99. Above this point the work was of quarry-faced granite backed with 1 : $2\frac{1}{2}$: 5 concrete; the coping stone was finished with 4-cut work on top, having quarry-faced edges with 2 in. draft line at top and bottom, the finished work being at grade 117.

PLATE I.
JOURNAL BOSTON SOCIETY
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OCTOBER, 1918.
FERNALD ON
MYSTIC RIVER BRIDGE.

DETAILS OF
PIERS 30 TO 36, INC.

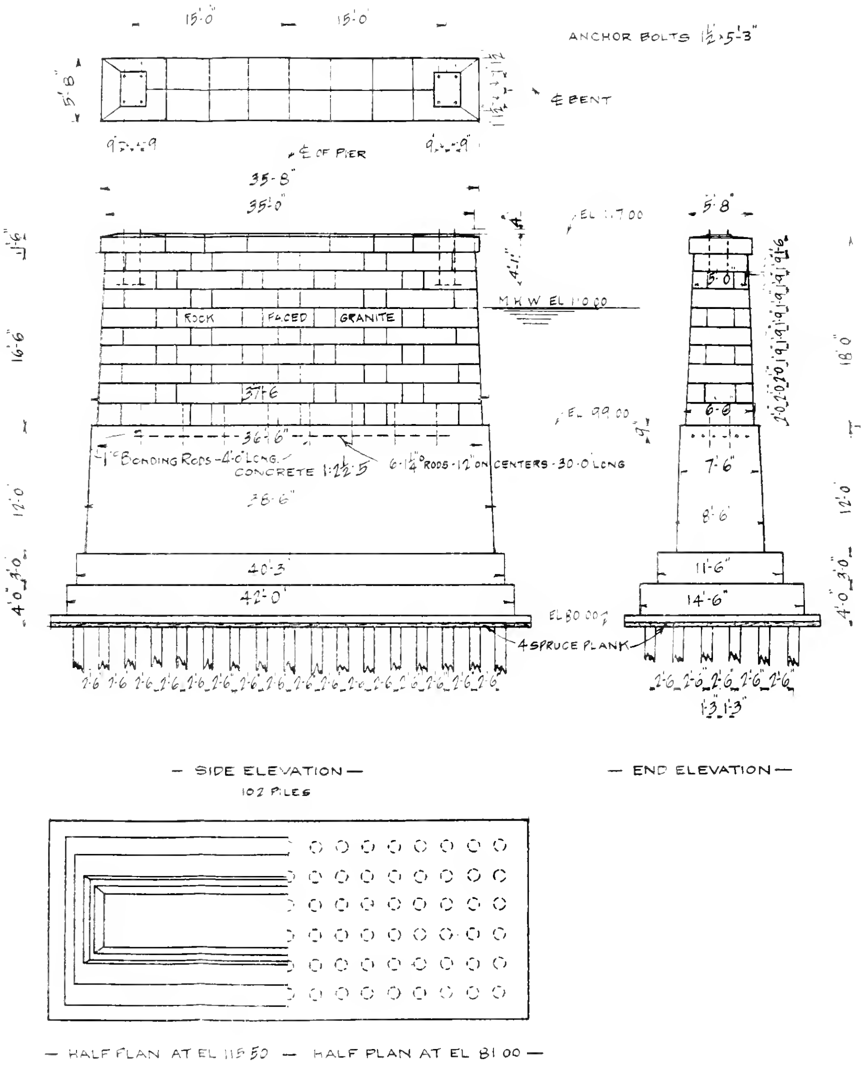

PLATE II.

JOURNAL BOSTON SOCIETY
OF CIVIL ENGINEERS.
OCTOBER, 1918.

FERNALD ON
MYSTIC RIVER BRIDGE.

DETAILS OF
PIERS 40 TO 44, INC.

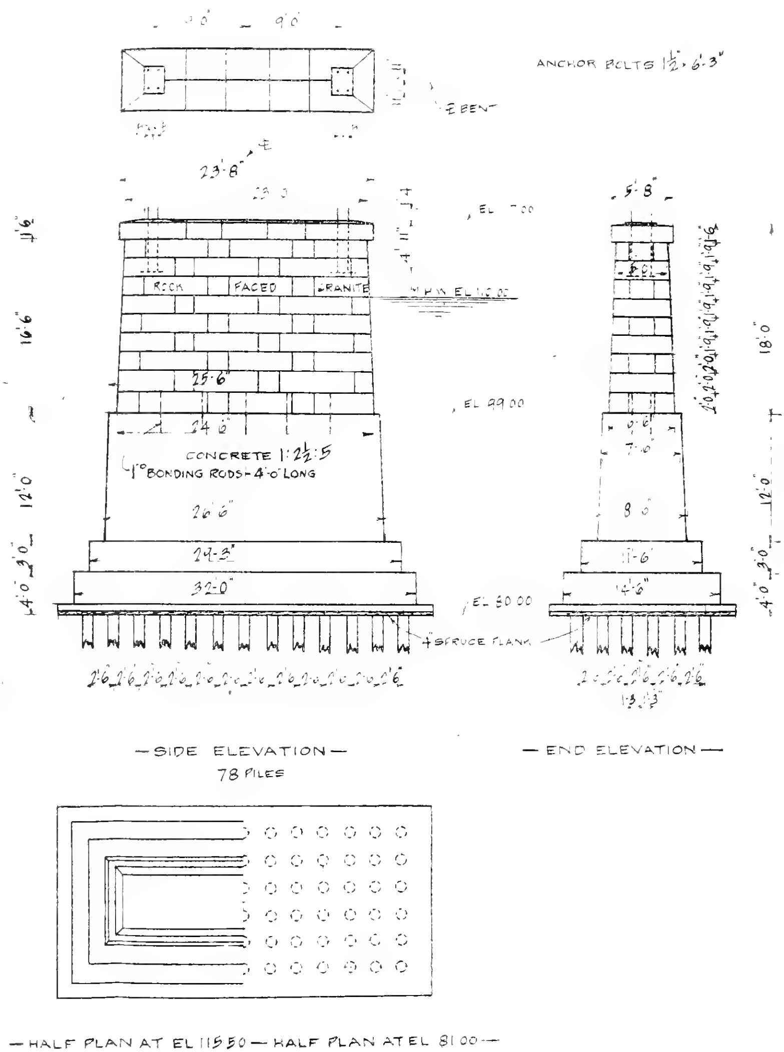

PLATE III.
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OCTOBER, 1918.
FERNALD ON
MYSTIC RIVER BRIDGE.

DETAILS OF PIER 37.

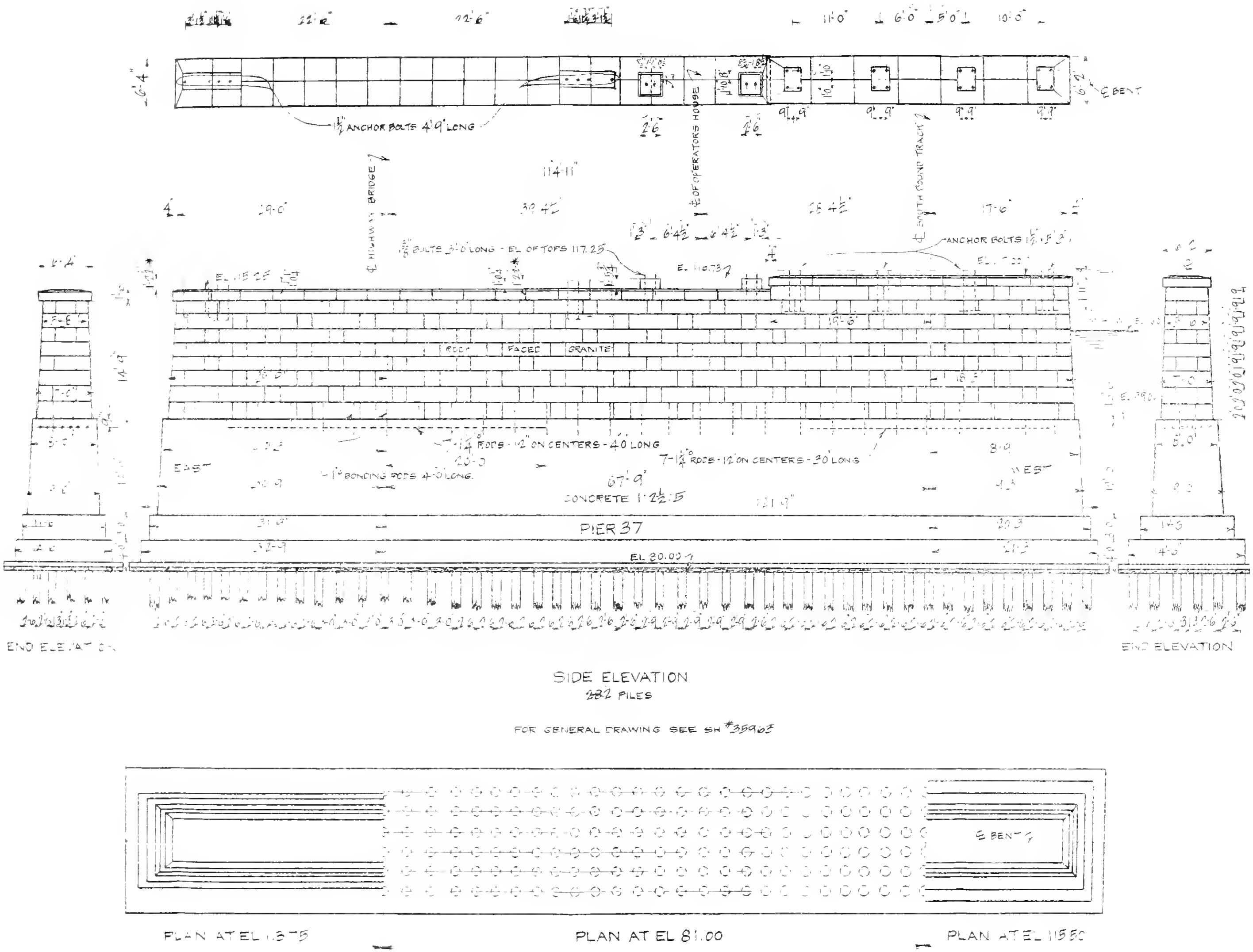

PLATE IV.
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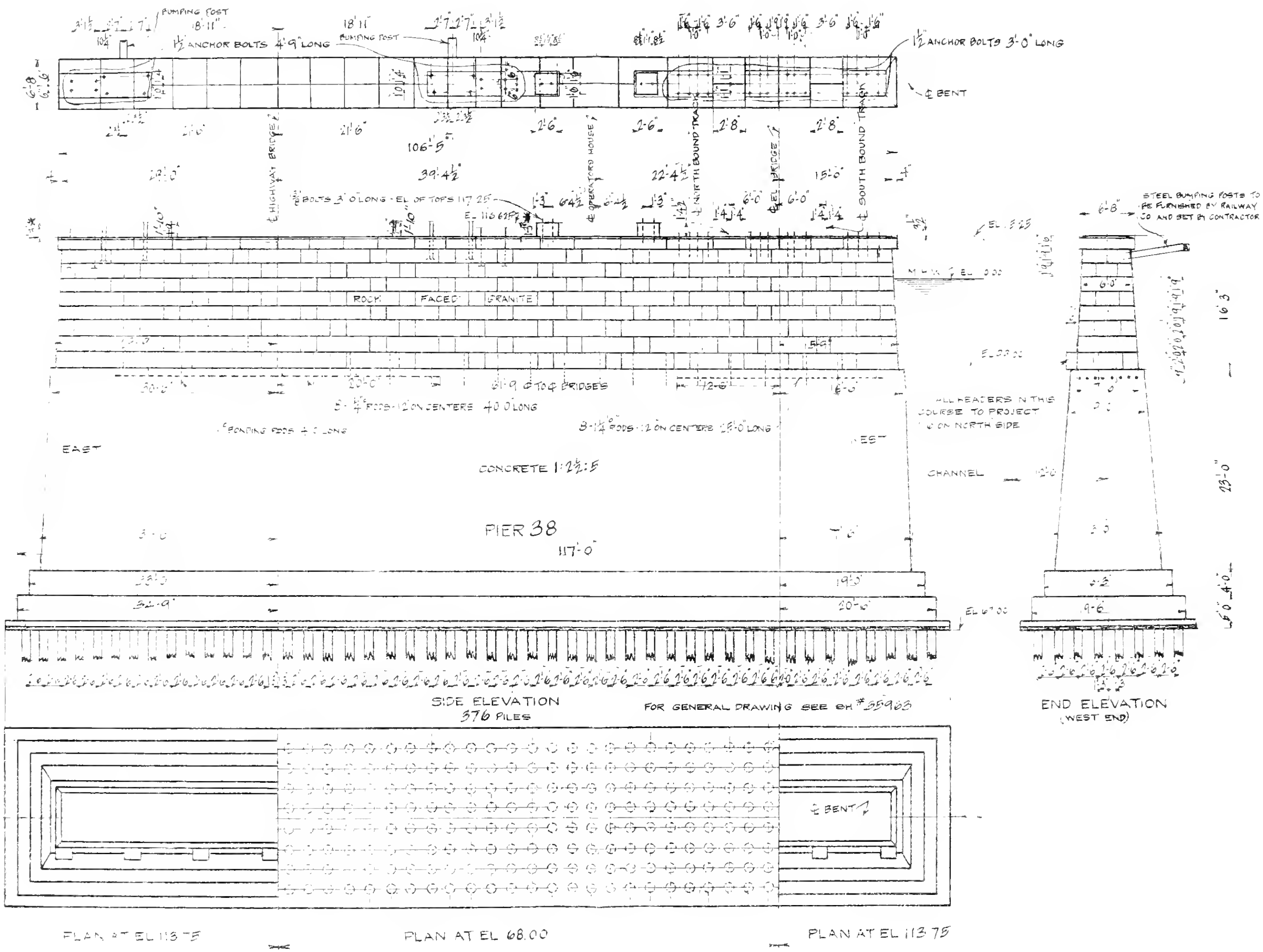
OF CIVIL ENGINEERS.
OCTOBER, 1918.
FERNALD ON
MYSTIC RIVER BRIDGE.

DETAILS OF PIER 38.



The four large piers at the draw were of special design, to meet the conditions imposed by their necessary depth, distribution of load, and methods of construction. The maximum load calculated for the piles was about 14 tons, assumed to occur when the bridges were open and subjected to a wind force of 15 miles per hour.

The minimum spacing for piles was 2.5 ft. on centers, and of course at points of heaviest loading.

Construction.

On March 20, 1916, a contract for the work was let to the Hugh Nawn Contracting Company.

The conditions controlling the construction of these bridges, and imposed by the necessity of keeping traffic moving over the old bridge as nearly normal as possible during its reconstruction, made the operations interesting at all times, and difficult at many others.

This traffic was to be maintained on one half of the old bridge, while the depth of the channel piers endangered not only its safety by undermining the piles, but its northerly abutment as well.

In addition to this, there was a 54-in. gas tunnel built through sand about 42 ft. down stream from the deep piers, and 11 ft. above their bottom.

On the northerly approach to the bridge the dredging necessary for the piers and sea wall caused a movement of the fill in the old street which at times gave considerable anxiety.

The first step taken, therefore, on the construction was to reinforce the floor of the down-stream half of the old bridge and draw, and relocate the outbound surface car track along this side of the old bridge.

Borings taken along the site of the new bridge indicated a bottom of soft or medium blue clay, overlaid with silt and gray sand varying from fine to quite coarse, and in depths of from 4 ft. to 20 ft. The bottoms of all the piers penetrated to this clay formation.

Dredging was begun on the northerly end of the bridge site, from near the north abutment of the old bridge to the abutment

of the new bridge. The soft material of sand and silt encountered here gave considerable trouble until the pier caissons were actually landed, as it was constantly pushing in from the street side.

Method of Constructing Piers.

The box-caisson method of construction was called for by the contract, in all cases except the channel piers, where four suggested methods were mentioned, viz., by box caisson, open concrete caisson, steel sheet piling cofferdam, which was to be finally removed, and by spliced steel sheet piling, the lower section to remain in place. The contractor built one of the channel piers (No. 38) by the latter method and the remaining channel piers (Nos. 39 and 39E), by the box-caisson method.

This method of construction proved to be very satisfactory and efficient. It was carried on by the contractor in the following manner.

The site of the pier was first dredged to a depth of about 3 ft. below the cut-off of the piles, which were then driven, and cut to grade by a circular saw mounted on the pile-driver gins. Guide piles were then driven around the site of the pier, the caissons floated in place, gradually sinking to position as the concrete forms inside them were filled.

Caissons.

The bottoms of the caissons were really concrete scows, the bottom dimensons being of the exact sizes of the pier footings and were 4 ft. in height, being divided into compartments about 9 ft. wide by cross partitions. Around the bottom there projected a lip or flange having eye bolts cast into it, to which the wooden sides were attached by hook bolts extending for the full height of the sides, and were tightened by set nuts seating on the top sills. (Fig. 2.)

The concrete caissons were built on ways, and launched at the north end of the bridge. The floor was of 3-in. spruce planks greased and laid on the ways in such a manner that by sawing through six planks the caisson was launched. The planks were thickly studded with 20*d*. nails to hold the concrete floor and sides which were cast directly in the forms.

FIG. 2. MYSTIC RIVER VIADUCT. CONCRETE BASE OF CAISSON ON WAYS.

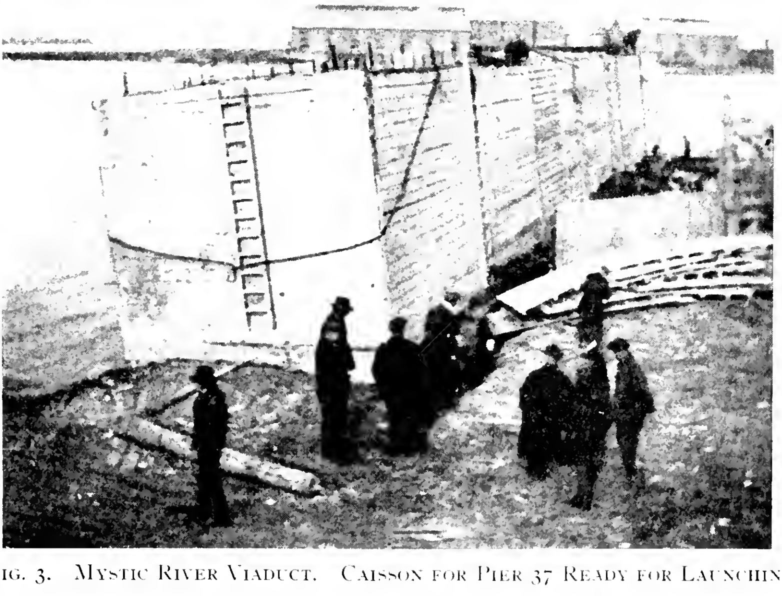


FIG. 3. MYSTIC RIVER VIADUCT. CAISSON FOR PIER 37 READY FOR LAUNCHING.

The caissons were thoroughly reinforced, the sides and flange being 12 ins., the bottom 6 ins., and partitions 9 ins. thick, made of 1 : 2 : 4 concrete.

Wooden sides were made in two sections, the bottom one being 16 ft. and the top one 17 ft. in height. The frame was of 10-in. by 10-in. and 10-in. by 12-in. hard pine, the bottom set was sheathed with 3-in. spruce planed, and the top set was sheathed with 2-in. spruce planed. The edges of the plank were beveled to provide for calking with oakum. These sides were used from three to four times each, and on account of their substantial and careful construction gave no trouble whatever; in most cases a single 3-in. duplex pump would handle all the leakage, in many instances under 14 ft. to 15 ft. head, by pumping a few moments at a time. (Figs. 3, 4 and 5.)

The advantages of this method were, economy of material, work all done in the dry, speed of operation and accuracy as to grade and alignment. The largest caisson sunk, which was 124.6 ft. long and 19.5 ft. wide, was successfully launched with lower sides in place, floated and sunk in place without trouble.

For pier 38, a cofferdam of 14 in. arched (35 lb.) Lackawanna steel sheet piling was used. This was spliced at grades 77 and 79 alternately for the tops of lower planks. Previous to driving this sheeting the area of the new channel piers and channel above and below the old bridge was dredged to grade 80. The up-stream half of the old bridge had been removed, and a bulkhead of oak piles with spur shores up stream had been driven to prevent a movement of the river bottom over the gas tunnel. Then the down-stream end of the steel cofferdam was driven close against the remaining half of the old bridge. After this the dredging was completed to grade 68 ±, the piles driven, and the tops were left at grade 71 ±.

In driving the 30-ft. piles for this pier and pier No. 37, it was found that they would go their full length with from four to five blows.

The pile driver used was a heavy Vulcan No. 1 steam hammer, weighing about 8 500 lbs., and, with the extension gins attached, made a total weight of between 5½ and 6 tons. Longer piles were decided upon, and new ones from 40 ft. to 45 ft. were

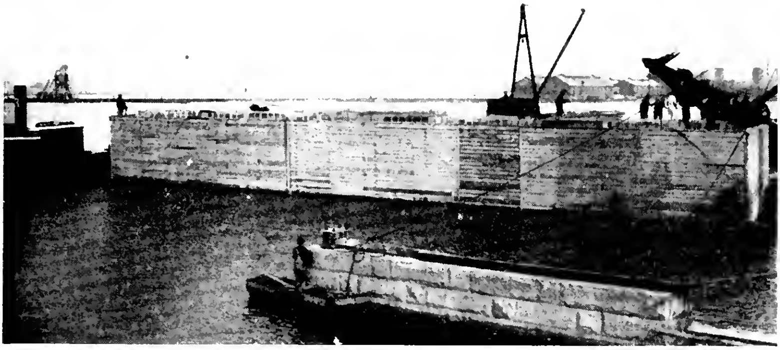


Fig. 4. Mystic River Viaduct. Floating Caisson.

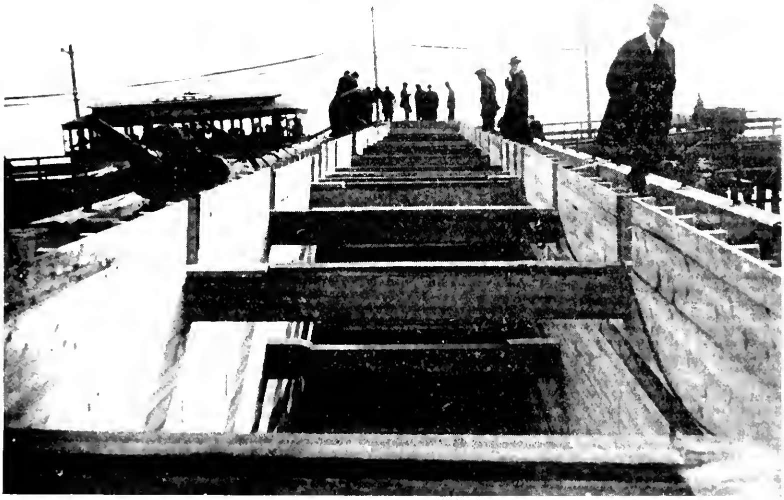


Fig. 5. Mystic River Viaduct. Top of Caisson.

driven. A test was made on one of each length of piles, the following morning, and it required eleven blows on the 30 ft. and thirteen blows on the 40-ft. pile to set them down one foot.

The steel cofferdam was then completed, after which concrete was deposited under water inside of it to grade 76 by means of bottom dumping buckets.

The cofferdam was then unwatered, and the balance of the work done in the dry.

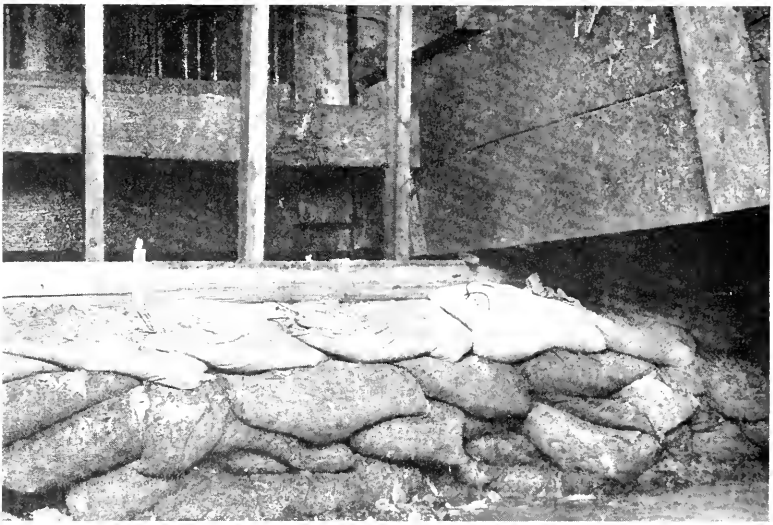


FIG. 6. TOP OF CONCRETE PIER 38 AT GRADE 76±.

Considerable difficulty was experienced in unwatering the cofferdam, due to lack of large pumps, at one time there being eight pumps at work, varying in size from 6 ins. to 15 ins. The 15-in. pump finally got the jump or initial head which tightened the pressure on the piling, and eventually succeeded in emptying the cofferdam. When once this was accomplished a single 6-in. pump took care of the leakage.

The top of concrete deposited under water was cleared, and the new work was carried on by building pockets of concrete mixed 1 : 2 : 4, placed dry in onion sacks. (Fig. 6.) These

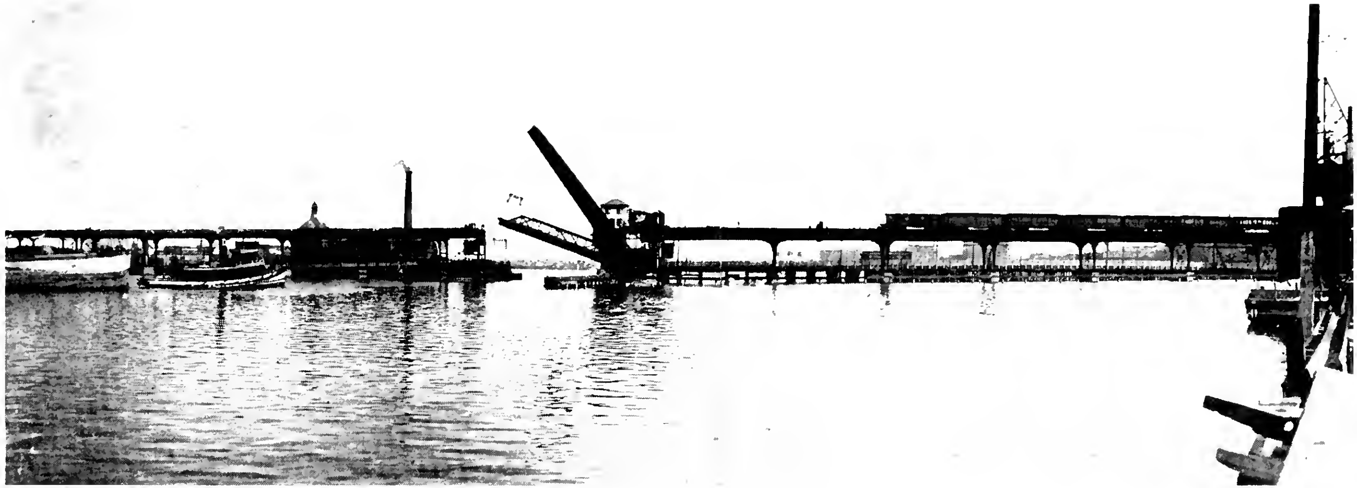


FIG. 7. GENERAL VIEW OF BRIDGE AND VIADUCT.

pockets were about 20 ft. long, 2 ft. high, conforming on the outside edge to the lines of the foundation; the dam of bags left a space of 2 ft. between it and the steel sheeting for drainage, and provided a dry interior for placing the new concrete. At times this work was carried on under 34-ft. head of water outside the cofferdam.

There was nothing of peculiar interest in the stone masonry work. The seats for all posts and bearings were left ½-in. high, to be dressed in the field to exact grade. This proved to be a wise precaution in several instances, as the coping stones were cut rather full. Fig. 7 shows the completed structure.

The construction work was carried on by the Hugh Nawn Contracting Company, having Mr. Kimball Garland, now first lieutenant in the 101st Regiment of Engineers (old First Corps Cadets) as designing engineer for caissons sides and caisson reinforcing.

The bridge was designed by Mr. Robert B. Davis, structural engineer of the Boston Elevated Railway Company, assisted by Mr. L. S. Cowles. Mr. Frederic H. Fay was consulting engineer.

The supervision of construction was in charge of the writer, assisted by Mr. William L. Blanchard, resident engineer, on the railroad bridge work, and Mr. John H. Coghlan on the highway bridge; and to the faithful and painstaking work of these two latter-named men the successful completion of the work owes no small share.

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PAPERS AND DISCUSSIONS

MYSTIC RIVER BRIDGE. DESCRIPTION OF SUPERSTRUCTURE.

By John C. Moses,* Member Boston Society of Civil Engineers.

(Presented September 18, 1918.)

The steel superstructure of the bridge over the Mystic River near Sullivan Square consists of four parts, — the highway draw, the railway draw, the operator's house and the railway viaduct. Both draw spans are of the Strauss bascule type.

The highway draw is designed to carry 50-ton electric cars and heavy city traffic. It consists of two pony trusses 12 ft. deep, with plate girder floor beams and steel stringers. The trusses are 102 ft. long from the center of the trunnions to the end bearing, and are 43 ft. apart, the sidewalks being carried on 8-ft. brackets outside of the trusses. The roadway floor has a wearing surface of 4-in. wide kreolited maple and beech planks, set on edge and laid at right angles to the roadway. They are supported by 4 in. by 8 in. hard pine longitudinal stringers laid 16 ins. on centers, and these in turn are carried by 6 in. by 8 in. hard pine cross ties spaced 2 ft. on centers and bolted to the longitudinal steel stringers at each bearing point. The sidewalks are of 2-in. plank, nailed to 4 in. by 6 in. spiking pieces that are bolted to the tops of the steel stringers.

*Engineer of Construction for the Boston Bridge Works, Inc.

Note. — Discussion of this paper is invited, to be received by W. L. Butcher, Editor, before December 10, 1918, for publication in a subsequent issue of the Journal.

One end of the span is carried by trunnions. These are steel shafts 16 ins. in diameter and 5 ft. long, that rest in bronze-lined boxes. The boxes are supported by triangular trusses that distribute the load to two piers 30 ft. apart. These piers extend up stream to carry the operator's house and the railway span. The main trusses extend 15 ft. beyond the trunnions and carry at these points a counterweight of 750 tons. This weight is a block of reinforced concrete 30 ft. by 20 ft. by 45 ft. in size, and supported by two posts that rest on pins in the trusses. These pins are in a straight line with the trunnion and the center of gravity of the entire span. The upper ends of the posts are connected by a link to posts that rest on top of the trunnions. This link, being parallel to the line from the trunnion to the counterweight pin, holds the weight always vertical, and the bridge is therefore in balance in all positions if balanced in any one position. The trunnions carry the live load as well as the dead load, the total amount being about 1 200 tons, and the pressure on the bearings about 2 000 lbs. per square inch. The counterweight contains pockets for varying its weight if found necessary at any future time.

The highway span is operated by a train of gears driven by two 35-h.p. motors, the last pinions of the train driving circular racks that are bolted to the trusses with the trunnions as their centers. (Fig. 1.) The rack teeth are $4\frac{1}{2}$-in. pitch by 10-in. face. All gearing and boxes are of steel. Motor-driven latches on the forward ends of the trusses hold the span fast when closed, and a 12-in. dashpot is provided, to lessen the jar when closing. A bumping post is built into the pier, to limit the opening movement.

The highway draw was erected in the closed position by a movable stiff-leg derrick with a boom of twenty tons capacity. Pile bents were driven to receive the truss as it was placed by the traveler. The same traveler erected the house between the two draw spans. A stationary stiff-leg derrick unloaded the material from the motor trucks that brought it to the site, and placed it on cars that carried it on a service track to the traveler.

The highway span contains about 300 tons of steel, 30 tons of machinery, and 50 000 ft. of lumber.

The railway draw consists of two deck plate girder spans, 120 ft. long, placed side by side and capable of being operated as one unit or separately. The forward ends of the spans are carried by the cross girder of the adjacent viaduct. The trunnions are carried by eight posts that also support the girders that carry the track of the viaduct on that side of the channel. The counterweights for this span are hung below the floor level. They are of very irregular shape, to clear the posts, girders, piers

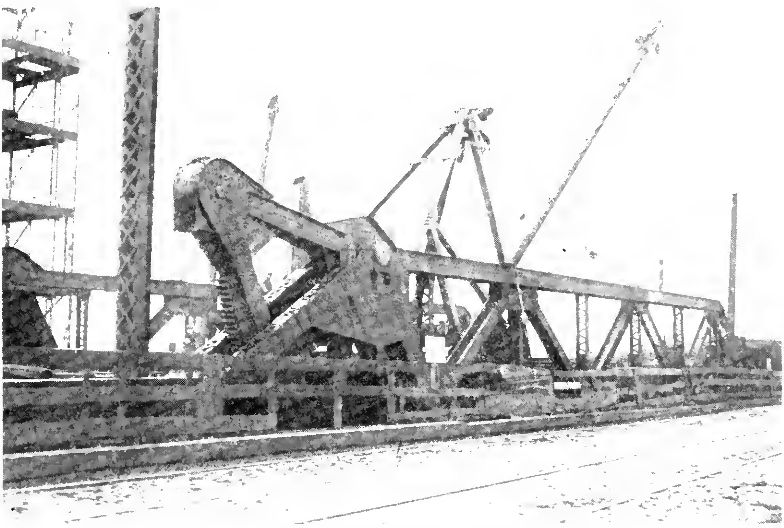

FIG. 1. HEEL END OF HIGHWAY DRAWBRIDGE, SHOWING COUNTERWEIGHT PIN AND RACK.

and other limiting features, and are heavily loaded with iron punchings to secure the necessary weight. There are two weights, each containing about 45 yds. of concrete. The front and rear portions of these weights are differently proportioned in order to obtain a weight per cubic foot of 170 lbs. and 202 lbs. respectively. An approximate balance about the point of suspension is obtained by this means, and links are provided in addition, to keep the weights in a vertical position during the movement of the bridge. The weights are also provided with pockets, for future adjustment if it is found necessary.

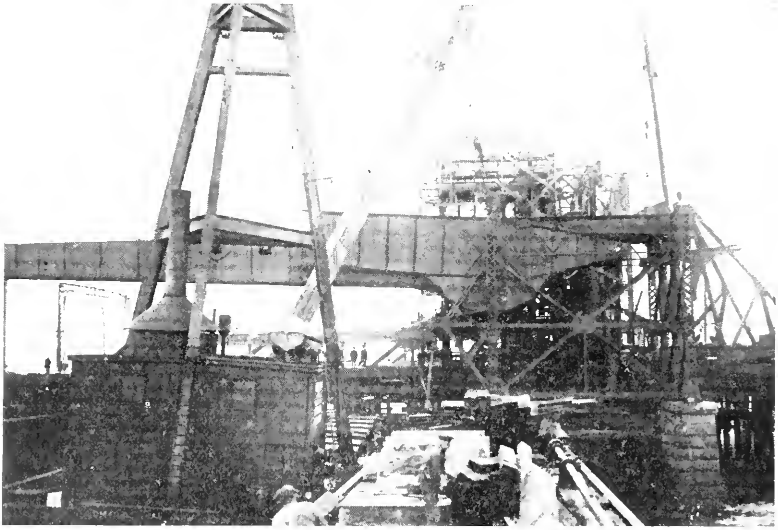

FIG. 2. ERECTING SEGMENTAL SECTION OF RAILWAY DRAW SPAN.

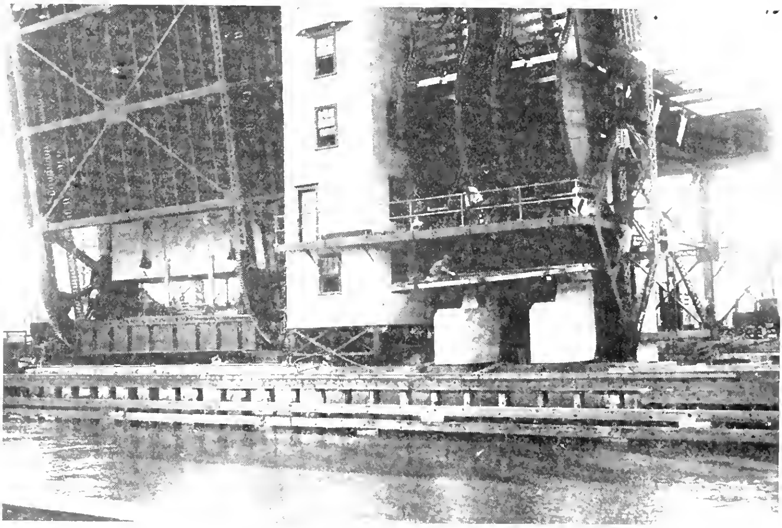

FIG. 3. UNDERSIDE OF DRAWBRIDGES, SHOWING POSITION OF COUNTERWEIGHTS.

The railway draw is operated by two 25-h.p. motors that drive racks bolted to the girders. It is locked in its closed position by motor-driven plungers that are supported by the adjacent viaduct and are supplied with current from the operator's house through a submarine cable.

The girders for this span were shipped from the shop in halves and were erected by a lighter that placed the trunnion halves first. (Fig. 2.) When these had been secured in place, the lighter placed the other halves with their outer ends supported by the viaduct, no falsework being required.

The railway draw contains about 160 tons of steel and 15 tons of machinery. A standard floor of ties with guard rails, track and third rails, walks, railings, etc., was laid by the forces of the Boston Elevated Railway.

The operator's house is between the two draw spans. It is a steel-frame building 13 ft. by 40 ft. in plan, and five stories in height, and contains about 25 tons of steel. The walls and floors are of concrete. The operator's room is the top floor. It contains two switchboards and the controllers, brake levers, signals, etc. The entire wire system for operating, lighting, signaling and protecting each bridge is kept separate from the other. Automatic cutout devices, interlocking mechanisms, lamp signals and other safeguards are provided to aid the operators and to prevent injury to the machinery from careless handling. The motors for the highway draw are under the sidewalks of the approach span, and are in metal houses that also cover most of the gearing and the mechanical brakes. The motors for the railway draw are in the second story of the house. All exposed gearing is protected by gear covers; and foot walks, stairways and ladders are provided for access to all parts. Fig. 3 shows the underside of the drawbridges, and Figs. 4 and 5 show the completed structure in operation.

The railway viaduct (Fig. 6) is about 1 700 ft. long, having 32 spans and weighing about 1 200 tons. It consists of four lines of plate girders supported by transverse girders that are supported in turn by two posts each. The details conform to the standards of the Boston Elevated Railway. The viaduct was erected by a lighter.

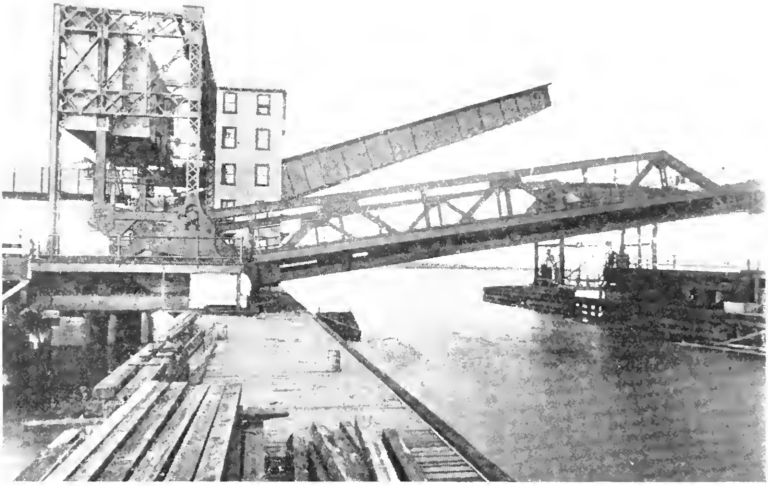

Fig. 4. Completed Structure in Operation.

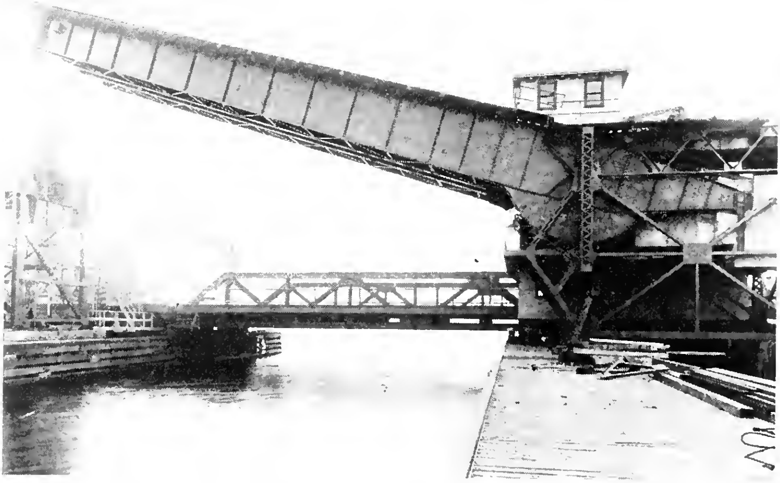

Fig. 5. Completed Structure in Operation.

The general contract for the superstructure was taken by the McClintic-Marshall Company, who sublet all but the viaduct to the Boston Bridge Works. General Electric Company motors were used. The Jennison-Wright Company furnished the kreolited planking, and the Hugh Nawn Contracting Company built the concrete counterweights. All the work was inspected in the shop and field by the Gulick-Henderson Company.

FIG. 6. GENERAL VIEW OF VIADUCT.

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BOSTON SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

PROGRESS REPORT OF COMMITTEE ON RUN-OFF.*

THE Boston Society of Civil Engineers' Committee on Run-off, appointed December 20, 1916, made a report to the Society which was published in the JOURNAL for April, 1918. Since that time the committee has met regularly each month with constantly decreased attendance, due to the fact that each of the members of the committee is doing two men's work in order to keep going the work of his office. It appeared almost necessary to give up active meetings of the committee until the end of the war, and some method was sought to keep up the interest in the work without requiring attendance on the meetings.

At a meeting of the Run-off Committee held September 18, 1918, the commitee voted to ask the Board of Directors of the Boston Society of Civil Engineers to publish advance chapters of its reports in bulletins, with the idea of making progress on the reports and giving members of the Society and others an opportunity to criticize and amplify the material of the subjects discussed.

The Secretary of the Society very kindly suggested that some of the advance material which had been prepared and discussed by the committee might be presented for discussion by members and others interested, in the form of advance copies published in the JOURNAL. The chairman has therefore prepared

* Members of committee: Arthur T. Safford, chairman; Charles H. Pierce, secretary; Harold S. Boardman, vice chairman; A. C. Eaton, X. Henry Goodnough, Richard A. Hale, Charles W. Sherman, Herbe A. Moody, W. Frank Uhl, Joseph F. Wilber, Dana M. Wood.

this statement, and offers a number of papers on different subjects which he hopes even in war times will call out some discussions which will be of advantage to the members of the committee when they have an opportunity to get all these matters in shape for a report. The list is as follows:

Glossary of terms.
Use of the current meter in stream gaging.
0.2 and 0.8 method in power canals.
Precipitation, evaporation and run-off.
Effects of ice on river discharge.
Methods to be used in compilation of data.

GLOSSARY OF TERMS.

1. *Precipitation* is water that passes out of the atmosphere, in liquid or solid state, to the surface of the earth or bodies of surface water. It includes rain, snow, hail, sleet, dew and frost. It is the process by which atmospheric moisture becomes surface water. Rainfall and snowfall make up precipitation as ordinarily used.

(*a*) *Rainfall* is sometimes used in the sense of "precipitation," but it should become more general practice to limit its use to atmospheric moisture precipitated in the form of rain. Its common use in the broader sense undoubtedly is the result of the practice of measuring all forms of atmospheric precipitation in terms of "inches of rainfall."

(*b*) *Snowfall* is considered as snow, hail, sleet and other forms of precipitation, except rain, measured in depth in inches as it falls, but usually appears in records as its water equivalent.

(*c*) *Snow residuum* is the accumulated snow on the ground surface at the end of any period, or its water equivalent.

(*d*) *Water equivalent* is the depth of water in inches to which the snow on a given area would melt.

(*e*) *An isohyetal map* shows variation in amount of average precipitation over contiguous areas and *isohyetal lines* are used to connect contiguous points of equal precipitation, similar to contour lines.

2. *Evaporation* is the return of water from the earth or water

surface to the atmosphere. It takes place in three or more ways, as from —

(*a*) Water, ice and snow surfaces; (*b*) land surfaces; and (*c*) vegetation, in the form of transpiration. Both evaporation and precipitation are the results of differences in temperature and atmospheric pressure.

3. *Seepage* or *percolation* of water is the movement of water underground, produced by hydrostatic pressure.

4. *Absorption* comprises all processes by which water is taken up by the earth's surface.

5. *Leakage* is the movement of water through artificial structures, and is produced by hydrostatic pressure.

6. *Discharge* is a general term for the rate of flow of water. In water-power practice, it is usually expressed in cubic feet per second (frequently abbreviated to second-feet); in water-works practice, it is customarily expressed in terms of million gallons per twenty-four hours.

7. The *drainage area* of a stream at a given point is the area of the surface of the earth which contributes its run-off to the stream above that point. Synonyms: Catchment area, watershed. The area used may be either gross, or the net exclusive of lake and pond areas, but it is assumed to be the former unless specified to the contrary.

8. The *run-off* of a given area of the surface of the earth is the quantity of water that is discharged from that area. Ordinary units of run-off are second-feet per square mile or run-off depth in inches.

(*a*) *Cubic foot per second* or *second-foot* is a unit of discharge of water flowing in a channel of one square foot in cross section at an average velocity of one foot per second.

(*b*) *Second-foot per square mile* is a unit of discharge indicating the average number of cubic feet of water flowing per second from each square mile of area drained, on the assumption that the run-off is distributed uniformly both as regards time and area.

(*c*) *Run-off depth in inches* is a unit of run-off indicating the depth to which the drainage area would be covered if all of the water flowing from it in a given period of time were conserved

and uniformly distributed on the surface. It is used for comparing run-off with precipitation, which is usually expressed in depth in inches.

9. The *yield* of a drainage area at any definite point is the amount of surface and underground waters contributed by it to a drainage system. If any of these waters are retained, either by natural or artificial storage within the watershed, the yield will not be the same as the run-off during the same period of time.

10. *Storage.*—The word usually means—

(*a*) *Artificial storage*, which is that water capacity which may be available to increase the extremely low flows for several days, weeks, months or even years. It is the retention of the flood waters for use during times of scarcity, and is usually located near the headwaters of a stream.

(*b*) There is usually some *natural storage* in the form of swamps, lakes and ponds, but its effect on stream flow cannot easily be separated from that of the rest of the drainage area.

11. *Pondage* is that water capacity created by any dam which tends to take care of the variations in draft at a water-power development. It is the retention for one or more days of the flow of a stream during hours of light load, for use during hours of heavy load.

12. *Factors:*

(*a*) *Load factor* is the ratio of the average to the maximum power load on a water-power plant during a given period of time, as a day, month or year. To be specific, this period should always be stated, as "daily load factor," etc. Frequently when plants operate for a period less than twenty-four hours, the load factor is expressed in terms of "load factor for hours when running"; but for purposes of stream-flow analysis all such factors should be reduced to the twenty-four hour basis.

In determining load factor, the "maximum load" should be the heaviest observed during the period. Usually, daily log records are kept, and switchboard instruments, when available, are read every half hour, or hour, and the highest of these observations is taken as the maximum.

The "average load" is the total energy output divided by the proper time unit.

(*b*) *Capacity factor* is the ratio of the average load in a given time period, as a day, to the total installed rated capacity of the equipment.

(*c*) *Utilization factor* is that coefficient by which the approximate theoretical energy-outputmust be multiplied to correspond to the actual delivered energy. It accounts for losses of all kinds, and for variations in operating conditions other than those included in the average plant efficiency.

The approximate energy available in a stream can be estimated by the following formulas.

I. Net horse-power at the water-wheel realizing 80 per cent. of the theoretical power $= \frac{\text{cubic feet per second x head}}{11}$.

If other than 80 per cent. is used as the efficiency of the equipment, then the formula should be —

$$\text{Net horse-power} = \frac{\text{cubic feet per second x head x efficiency}}{8.8}.$$

II. Electrical horse-power (73.3 over-all efficiency) =

$$\frac{\text{cubic feet per second x head}}{12};$$

or,

$$\text{III. Kilowatts} = \frac{\text{cubic feet per second x head}}{16}.$$

Losses allowed for in the utilization factor are leakage and waste in operation, etc.

Changes in efficiencies may be due to variations in load or variations in head from the average assumed for use in the formulas.

13. *River gaging stations.*

(*a*) *Control* is the natural or artificial barrier, reef of ledges or other channel conditions below a gaging station which primarily affects and controls the relation between gage height and discharge at the station. It should be noted that the control may not be the same section for all stages.

(*b*) *Rating table* for a gaging station is a table showing the discharge corresponding to various gage heights at the station.

(*c*) *Rating curve* for a gaging station is a curve of relations between gage height and discharge.

(*d*) *Stage-discharge relation* is the relation between gage height and discharge as shown by the rating curve, q. v.

(*e*) *Water-stage recorder* is an instrument for automatically recording the elevation of the water surface, and the corresponding time.

14. *Regulation* is the artificial manipulation of the run-off of a stream.

15. *Fall* is the vertical distance between water surface levels at two points on a stream under static flow conditions.

(*a*) *Gross head* is that portion of the fall which is available for producing power.

(*b*) *Net* or *effective head* is the residue left to produce energy after deducting all losses of head. These losses may be due to friction, irregularities of section and other causes.

(*c*) *Slope* is the total fall between two points divided by their distance apart, expressed in the same units.

16. *Dams:*

(*a*) *Crest of a dam* is, in general, the top of the fixed overflow structure. In some cases there may be overflows at several elevations.

(*b*) *Height of a dam* should be specifically defined as either: I, from the bottom of foundations to the top of the structure; or II, from the original bed of the river to the crest of the dam.

17. *Backwater.* — This is the general term applied to the raising of water upstream from an obstruction to higher elevations than it would stand under similar conditions of flow with no obstruction. Such an obstruction may be a permanent structure like a dam or bridge pier, or may be a temporary obstruction like ice or logs. An unusually heavy discharge from a tributary may cause backwater in the main stream or vice versa.

(*a*) *Backwater curve* is a profile of the water surface upstream from an obstruction between such obstruction and the point where the backwater ceases. Such a curve or profile is used in determining the elevation of the water at any point under known or assumed conditions of flow. Each different set of conditions produces a different backwater curve.

(*b*) *Backwater effect* is the increase in water-surface elevation caused by an obstruction, and varies with the discharge. It may be obtained at any point by a comparison of the backwater curve and the natural profile of the stream with no obstruction, each referred to the same discharge. In discussions on this subject the term *backwater effect* is sometimes shortened to *backwater*.

THE USE OF THE CURRENT METER IN STREAM GAGING.*

About thirty years ago, at the time of starting the work of the Irrigation Survey, which later developed into the Reclamation Service, attention was called to the necessity of devising some simple means of accurately measuring the flow of water in natural streams. The first annual report of the Irrigation Survey, J. W. Powell, director, contains a very complete history of the early stages of hydrometric work, including a description of the training school for hydrographers which was held at Embudo, N. Mex., from November, 1888, to April, 1889. Mr. F. H. Newell, later director of the Reclamation Service, and now professor of civil engineering at the University of Illinois, was placed in charge of the camp and presumably directed and assisted the fourteen young men who were selected to take the practical course in what may be called the "First Principles of Stream Gaging." Prof. George E. Curtis of Washburn College, Topeka, formerly in the United States Signal Service, was also an instructor at the camp, and apparently had charge of the meteorological division of the work.

Capt. C. E. Dutton of the Ordnance Corps, U. S. Army, temporarily on duty with the Geological Survey, was the officer in general charge of the organization of the hydraulic survey and the engineering survey, which, with the topographic survey, were undertaken to secure the base data required for the successful prosecution of the immense irrigation projects about to be undertaken in the West.

* By C. H. Pierce.

The report of Captain Dutton, dated November 1, 1889, contains much of interest to present-day engineers. It should be kept in mind that, in his discussion of methods and equipment, Captain Dutton was referring to the measurement of water in natural stream beds for the purpose of determining the probable average daily flow of those streams, and that he was not concerned with the measurement of water in power canals, or with precise methods of determining the efficiency of water wheels.

In his report Captain Dutton said:

"The measurement of water flowing in a stream is not an easy matter. It requires skill and rather costly instruments. While the general method has been the subject of much inquiry by a few men, and has been practiced to a small extent, there is a wide variation in details and considerable uncertainty or discordance in results. At the beginning of the organization there were no men available who possessed the requisite experience and skill except two or three men who were occupying responsible positions, and it was doubted if they could be induced to relinquish them. Neither were any instruments to be found in the market as articles in regular supply, and such as were needed must be made to special order. . . . In view of the novelty of the work thus involved upon the Survey, of the impossibility of finding men skilled in the work required, of want of instruments adapted to the work, and in further view of the fact that the winter was near at hand, during which the field work would, in most portions of the West, be impracticable, it was deemed best to select a small body of young men of good education and high general intelligence and establish them at some advantageous station where they could, in the course of the winter months, acquire a knowledge of the methods and instruments they would have to employ. Fourteen young men were carefully selected and were placed in a camp of instruction, situated at Embudo, on the Rio Grande River, about fifty miles north of Santa Fé, in New Mexico, where they passed the winter in practicing with the various instruments selected for trial and in becoming familiar with the theory and practical application of the methods. In the month of April the camp was broken up and the men distributed to their respective fields of work.

"The camp of instruction at Embudo was placed in charge of Mr. F. H. Newell, and the work required of the men consisted in practical stream gaging by various methods, measuring the rise and fall of the stream from day to day, measuring the daily evaporation and making observations with meteorological instruments.

"*Stream Gaging.*

"In measuring the flow of streams, it is to be remembered that the flow varies from time to time. The measurement made on any given day, while the river keeps a steady flow for an hour or two, is good only for that day and hour, and for times when the river is at the same stage. A small rise in the stream is accompanied by a large increase in the flow, and a small fall by a large decrease in the flow. To ascertain the flow during a considerable period of time and thus obtain an average for varying stages, two distinct classes of measurement are necessary: First, the amount of flow corresponding to each and every stage; second, a continuous record of the rise and fall.

"(1) Measurement of flow. — There are four methods of gaging the flow of a stream: (*a*) by weirs; (*b*) by floats; (*c*) by formula; (*d*) by meters.

"Weirs are practicable and economical only in the case of small streams at low water, and in such cases the system is preferable to all others. When the depth of the water passing over the weir much exceeds a foot it becomes sometimes uncertain. In streams not exceeding 25 to 30 ft. in width, and carrying not more than 40 or 50 cu. ft. of water per second, a weir may be constructed quickly and cheaply. It is almost certain to be swept away by high water, but if small and in shallow water it can be easily replaced. It is desirable, however, to select stations where the water above the weir has no sensible 'velocity of approach' other than that produced by the constant movement of water over the weir, as it is difficult to make proper allowance for it.

"Gaging by floats is the crudest and most unreliable of all methods. It consists in throwing floating objects into the water and noting the length of time occupied by the float in moving through a measured distance down the stream. The distance divided by the time is the mean velocity of the motion of the float. But this velocity of the float is not the mean velocity of the stream, which varies in different parts of the width and at different depths. As a rough-and-ready rule the mean velocity of the stream is taken to be about four fifths the velocity of the float. This is no doubt a fair approximation where the cross section of the stream is symmetrical, the current smooth, regular and free from eddies, and its course free from obstructions. But in small or medium-sized rivers such conditions are rare, and the whole method of measurement is liable to great uncertainties, and it is impracticable in large rivers.

"Gaging by formula is based upon the assumption that with a given cross section the mean velocity of flow bears a

certain ratio to the declivity down which the water moves. The declivity may be accurately ascertained by the spirit level. With a given declivity the flow will vary with the cross section, being greater when the latter is narrow and deep than when it is broad and shallow. The effect of the form of the cross section has been experimentally investigated by several hydrographers and an empirical formula has been devised for it which seems to give very fair results when the cross section is not of very irregular form and when the bottom is not incumbered with large stones and other obstacles. In general, however, it is of very limited utility.

"Gaging by meters is the most satisfactory and complete method of all. The ordinary current meter is a small wheel which is caused by the current to revolve when immersed. It may be of propeller, windmill, or anemometer form. The axis of the wheel is attached to some device for recording automatically the number of revolutions in a unit of time which corresponds to any given velocity; in other words, every meter must be 'rated.' In all good meters the number of revolutions bears a simple ratio to the velocity of the stream unless the velocity is very small. At very low velocities even the best form of meters becomes irregular and uncertain. They are also inferior to weirs for very small or very shallow streams. In gaging with a meter, the cross section of the stream is subdivided into portions 5 ft. wide in ordinary streams and 10 ft. wide in very broad ones. The form of the bottom and areas of subdivisional cross sections are ascertained by soundings, and the mean velocity of each is measured with the meter. Each subdivision is therefore treated as a separate stream and the flow of the entire stream is the sum of the flows of its constituent parts.

"The object of this camp was to train the new members of the hydrographic division for active and independent field work for the succeeding seasons. The principle under which the operations at the camp were conducted was to attempt all those investigations which seemed pertinent to the future work of the Survey, modifying from time to time the methods and instruments as experience developed obstacles or objections.

"A regular routine of observations was begun and carried on, by which each man in turn became familiar with the details of each investigation; but beyond this the fullest possible scope was left for individual development, and opportunity for original work in such lines of research as each should choose.

"A small rope ferry was established near the camp across a suitable part of the river, and various forms of meter used for obtaining the velocity. Changes and improvements in the meters were suggested while experience was being acquired.

"From the results obtained by the meters the velocities in various parts of the river's cross section were determined and both horizontal and vertical curves of velocity were plotted, making a comparative study under various conditions.

"While meters were being used at one part of the river other methods of stream measurement were tried at suitable points, i. e., by surface floats, subsurface floats and vertical rods. Comparisons were made between the results obtained in these various ways as well as by the formula for river flow given by Kutter.

"Records of the river height were kept continuously and a study made of the relation between river height and discharge. These records were kept both by observation and by an automatic recorder or 'nilometer' which was installed and tested as to its suitability for this work."

Beginning with the experimental work at the Embudo camp, and during the subsequent work which was soon being carried on in different parts of the country, it was seen from the vertical curves of velocity that certain general laws applied to the velocity of the moving water in a vertical section of a natural stream. At the present time these laws are better understood, and are generally covered by a statement that, in a section of a river where conditions are suitable for current-meter work, the variation in the magnitude of the velocities in a vertical section may be closely represented by a parabola, the axis of which is, in general, below and parallel to the water surface. The exact size and shape of this parabola of velocities will continually vary throughout the width of the stream, so it follows that the measuring sections must be taken sufficiently close together to determine the variation of velocity in the horizontal section.

From the general shape of the vertical curves of velocity it was thought that the average velocity in the vertical section could be determined from a measurement of the velocity at some one point in the section, and a large amount of experimental work was done to determine the coefficient to be applied to reduce the observed velocity to a mean for the vertical section.

It must be remembered that the scope of the work was such that whatever methods were used must be applicable to streams varying greatly in size, some gagings being made where the depth of water was not more than 1 foot, whereas other gag-

ings must be made where the depth was 40 or 50 feet, the hydrographer in some cases working from a bridge perhaps 25 or 30 feet above the water surface, and in other cases working from a car swaying from a cable in mid-air. He usually works alone, and must make accurate soundings of the depth from water surface to river bottom; he must place and hold the meter at the proper point or points for the observations; he must count the number of revolutions of the meter and obtain the corresponding time by the stop-watch; he must keep his note-book convenient and record the results at the end of every observation; and, in the case of high velocities, he may find it necessary to operate a stayline to keep the meter in the proper position in the vertical section.

Under these conditions of the problem, it was necessary to simplify methods as much as possible, and although it was realized that observations of velocity at many points in the vertical section might be desirable, that method was generally impracticable on account of the time required. Any advantage due to ultra-refinement in the determination of velocity in any one section might be entirely lost by a change in stage of the river during the extra time required by the ultra-refinement.

It was early seen that for a single observation taken at 0.6 of the depth the coefficient to reduce to mean velocity was generally very close to unity, the difference being positive about as often as negative, and generally not exceeding a few hundredths. This 0.6 depth method was accepted as the standard for several years, although frequent vertical curves were obtained and numerous studies and comparisons were made.

During 1901 and 1902 a series of observations were made on the flow of rivers in the vicinity of New York City, the results of which are described in U. S. G. S. Water-Supply Paper No. 76, which is illustrated by numerous curves and diagrams showing the shapes of velocity curves for various types of streams and different conditions of stream beds.

In 1903 the writer made numerous comparisons and plotted many vertical curves of velocity for streams in Vermont, and engineers in other sections of the country were making similar tests of the method. In 1904 the second and enlarged edition

of "Accuracy of Stream Measurements," by E. C. Murphy, was published as U. S. G. S. Water-Supply Paper No. 95. Besides giving the results of Murphy's Cornell experiments, this paper contains tabulations showing the results of a large number of measurements by different methods and under various conditions. Soon afterward, in 1905, the method known as the "0.2 and 0.8 depth method" was brought out, as being more reliable than the single-point method, and yet simple enough to be easily used. In addition to a theoretical proof, thousands of tests and comparisons of this method have been made, a summary of which is contained in Hoyt and Grover's textbook on "River Discharge." This textbook should be referred to by any one desiring detailed information as to the results of the comparisons; the general summary shows that of 476 curves the average coefficient needed to reduce the mean of the 0.2 and 0.8 depth observations to the true mean was 1.001, the highest coefficient for any curve being 1.026 and the lowest coefficient 0.970. This shows an average error of one tenth of one per cent. with a maximum individual error of 3 per cent.

Mr. R. A. Hale, of Lawrence, Mass., has contributed valuable data showing the results of the use of the 0.2 and 0.8 depth method in rectangular flumes and canals. Twenty-three measurements made in five different conduits show that the average coefficient needed to reduce the mean of the 0.2 and 0.8 depth observations to the true mean was 0.993, the highest coefficient for any curve being 1.028 and the lowest coefficient 0.945.

The use of the current-meter should presuppose a knowledge of its proper use. Like most scientific instruments, it can only be used to advantage by those familiar with the instrument and with its limitations. While it cannot be expected to compete with the chemical or electrochemical methods of measurement of water through turbines, on the other hand those latter methods cannot compete with the current meter in obtaining the data on the run-off of rivers which are generally needed for water-power studies. With a method of measurement which gives results averaging less than one per cent. in error it would seem that further refinement of methods would be unwarranted, considering the uncertainties which enter into any water-power

study, and the fact that previous conditions of flow are not likely to be exactly duplicated in the future.

An interesting and instructive discussion of the history and vicissitudes of the current meter in the United States is contained in the Proceedings of the Engineer's Society of Western Philadelphia for June, 1914, where Mr. N. C. Grover describes current meter work and also gives an interesting account of the work of the hydrographer and a description of the varied conditions he must be prepared to meet.

In conclusion it may be said that the 0.2 and 0.8 depth method which is now widely used is the result of many years of study and investigation by engineers in all parts of the United States. Since, however, this method has been adopted as an improvement over other good methods, it is to be hoped that still further improvement may be made, and that any errors still existing may be finally eliminated.

0.2 AND 0.8 METHOD OF CURRENT METER MEASUREMENT IN POWER CANALS.*

A long, straight section of river or power canal, where the alignment is good and where the sides and bottom are free from obstructions and fairly smooth, thus giving the water a good chance to flow uniformly and without eddies and whirls, offers the best chance for accuracy with the 0.2 and 0.8 method of current-meter measurement.

Conditions approaching the ideal are found most readily in the larger rivers with sandy bottoms — never in mountain streams and very rarely in power canals.

In any case, after a section has been selected with due care for manner of approach of the water, freedom from backwater and as good conditions with ice cover as possible, multi-point traverses should be made in order to establish definitely whether the 0.2 and 0.8 method may be used in future measurements, or whether the 0.6 or integrating methods will give better and more accurate results. Where the section and alignment is good, the

* By Arthur T. Safford.

bottom and sides smooth, and water is not fed in or taken out irregularly, the 0.2 and 0.8 method may be found to give accurate results.

In the case of power canals, such conditions are rarely encountered. Power canals are generally relatively short, water is fed in at the head, sides or both, through gates, one or more of which may be wholly or partly open at different times, and water is taken out at the end or at various places along the canal in all manner of ways. In addition, such canals are liable to be bridged at short intervals with the bridges carried on piers or posts, to contain ice or log booms, and even to be crossed by pipe lines at or near the bottom. All these and similar obstructions cause eddy currents and whirls, and even the smallest obstruction may cause a large variation in the normal distribution of velocities. The 0.2 and 0.8 method may in such cases be found to be several per cent. high or low, even if the vertical sections are taken very close together.

There are many examples of velocity distribution in power canals which might be cited to prove the inaccuracy of using the 0.2 and 0.8 method without having previously made multi-point measurements to determine accurately the velocity distribution. A few examples of such conditions follow. (Table 1.)

During the test of a 54-in. R. H. McCormick wheel at the Holyoke Water Power Company testing flume, October 16, 1900, the results obtained for head and discharge were very carefully investigated. During the actual test of the wheel at full gate opening, about 14.6-ft. head and from 108 to 109 R.P.M., the load was held constant long enough for measurements to be made from a horizontal straight-edge down to the water-surface to check the agreement of the two hook gages, and at the same time two multi-point current meter measurements were made, one 6 ft. up from the weir, the other 10 ft. up from the weir or directly over the 1-in. pipe to the still-boxes. The horizontal straight-edge consisted of a beam across the flume above the 1-in. pipe with seven nails set 1, 4, 7, 10, 13, 16 and 19 ft. from the left side of the flume and very carefully leveled. Readings were made from these nails to the water-surface by use of a hand-hook gage. Readings were also made at three other points 16 ft.

TABLE 1.

Comparison of Mean Velocities with 0.2 and 0.8 Velocities in Power-Canal Measurements.

**Pawtucket Canal — Lowell — at Upper Side of Hamilton Footbridge to Blue Dye House. March 29, 1918*, P.M.

Station.	Depth. Feet.	Mean Velocity. Ft. per Sec.	Velocity. Ft. per Sec. 0.8 Depth.	Velocity. Ft. per Sec. 0.2 Depth.	Mean Ft. per Sec.	Ratio Mean of 0.2 and 0.8 Velocities to Mean Velocity in Per Cent.
3	9.5	3.83	3.09	4.12	3.61	94.2
10	11.7	3.26	2.48	4.04	3.26	100.0
17	11.6	4.87	4.83	4.24	4.54	93.2
27	12.3	5.59	5.91	4.90	5.40	96.6
36	12.4	5.05	4.73	4.97	4.85	96.0
45	12.0	4.71	4.12	5.24	4.68	99.4
54	12.0	4.56	4.13	5.71	4.92	108.0
63	12.0	3.88	3.35	4.29	3.82	98.4
72	11.7	3.50	2.70	4.23	3.47	99.1
81	9.4	3.45	2.64	3.95	3.30	95.6
90	7.1	3.05	2.74	3.28	3.01	98.7
95	5.8	2.99	2.26	3.48	2.87	96.0
		4.06			3.98	98.0

Lawrence Manufacturing Company. Nos. 4, 5, 6 Raceways.

July 26, 1910. Right-hand Raceway No. 16–151.

Station.	Depth. Feet.	Mean Velocity. Ft. per Sec.	0.8 Depth.	0.2 Depth.	Mean Ft. per Sec.	Ratio in Per Cent.
1	1.70	6.050	6.25	5.85	6.05	100.0
2	1.70	6.696	6.79	6.74	6.765	101.1
3	1.70	6.279	5.91	6.92	6.415	102.2
4	1.70	6.633	6.62	6.93	6.775	102.2
5	1.70	6.530	6.45	6.77	6.61	101.3
6	1.70	6.335	6.14	6.75	6.445	101.9
7	1.70	6.392	6.30	6.77	6.535	102.3
8	1.70	6.169	6.06	6.51	6.285	102.0
9	1.70	5.891	5.70	6.24	5.97	101.5
10	1.70	5.482	5.40	5.74	5.57	101.6
11	1.70	4.818	4.84	4.97	4.905	101.9
		6.116			6.211	101.6

August 5, 1910. Left-hand Raceway No. 18–151.

Station.	Depth. Feet.	Mean Velocity. Ft. per Sec.	0.8 Depth.	0.2 Depth.	Mean Ft. per Sec.	Ratio in Per Cent.
1	1.81	3.544	3.45	3.57	3.51	99.0
2	1.81	5.514	4.85	6.32	5.585	101.4
3	1.81	6.300	5.71	6.95	6.33	100.5
4	1.81	5.909	5.27	6.63	5.95	100.7
5	1.81	6.249	5.56	6.87	6.215	99.4
6	1.81	5.558	5.15	5.98	5.565	100.2
7	1.81	4.569	4.42	4.55	4.485	98.1
		5.378			5.377	99.9

* Not exact.

TABLE 1. — *Continued.*

Saco-Lowell Shops. Nos. 1 and 2 Wheels. October 24, 1916, P.M.

Station.	Depth. Feet.	Mean Velocity. Ft. per Sec.	Velocity. Ft. per Sec. 0.8 Depth.	0.2 Depth.	Mean Ft. per Sec.	Ratio Mean of 0.8 and 0.2 Velocities to Mean Velocity in Per Cent.
1	5.76	2.15	1.99	2.28	2.145	99.8
4	5.76	2.25	2.19	2.31	2.25	100.0
7	5.76	2.19	2.10	2.22	2.16	98.6
10	5.76	1.72	1.59	1.82	1.705	99.1
13	5.76	1.36	1.24	1.48	1.36	100.0
16	4.94	1.15	1.07	1.20	1.135	98.7
18	4.44	0.88	0.90	0.93	0.915	104.0
		1.67			1.667	100.0

Lawrence Manufacturing Company. Nos. 1, 2, 3 Races. August 5, 1910. Left-hand Race.

0.3	2.60	1.307	1.45	1.22	1.335	102.1
2.	3.80	1.514	1.58	1.50	1.54	101.7
4.5	5.90	1.814	1.88	1.84	1.860	102.5
7.	6.50	1.656	1.66	1.78	1.72	103.9
9.5	5.70	1.749	1.64	1.64	1.64	93.8
12.	3.90	1.630	1.53	1.77	1.65	101.2
13.9	1.80	1.409	1.33	1.55	1.44	102.2
		1.583			1.598	101.1

Right-hand Race.

0.3	2.20	0.468	0.63	0.36	0.495	105.7
2.	4.00	0.989	0.98	1.02	1.00	101.1
4.5	5.80	1.206	1.20	1.14	1.17	97.0
7.	6.60	1.226	1.19	1.28	1.235	100.7
9.5	5.50	1.339	1.33	1.38	1.355	101.2
12.	3.50	1.319	1.32	1.34	1.33	100.9
13.9	1.80	1.035	1.02	1.09	1.055	102.0
		1.083			1.091	101.2

Bigelow Carpet Company at Entrance to Feeders. October 5, 1911.

L. H. Feeder........	5.23	4.35	6.67	5.51	105.2
Middle Feeder......	4.45	4.53	4.50	4.51	101.5
R. H. Feeder.......	5.00	5.84	4.50	5.17	103.5
	4.89			5.06	103.4

**Holyoke Testing Flume — 10 Ft. up from Weir. October 16, 1900.*

1.	8.052	1.27	1.25	1.51	1.38	108.6
4.6	8.052	1.50	1.50	1.80	1.65	110.0
8.2	8.052	1.76	1.84	1.84	1.84	104.5
11.8	8.052	1.57	1.70	1.78	1.74	110.8
15.4	8.052	1.26	1.36	1.22	1.29	102.4
19.	8.052	1.30	1.15	1.55	1.35	103.8
		1.475			1.577	107.0

* Not exact.

TABLE I. — *Continued.*

**Holyoke Testing Flume — 6 Ft. up from Weir. October 16, 1900.*

Station.	Depth. Feet.	Mean Velocity. Ft. per Sec.	Velocity. Ft. per Sec. 0.8 Depth.	Velocity. Ft. per Sec. 0.2 Depth.	Mean Ft. per Sec.	Ratio Mean of 0.8 and 0.2 Velocities to Mean Velocity in Per Cent.
1.	8.052	1.12	0.64	1.46	1.05	93.7
4.6	8.052	1.43	1.25	1.48	1.37	95.8
8.2	8.052	1.75	1.60	1.90	1.75	100.0
11.8	8.052	1.68	1.45	1.89	1.67	99.4
15.4	8.052	1.34	1.22	1.37	1.29	96.2
19.	8.052	1.32	1.13	1.62	1.38	104.5
		1.484			1.459	98.3

**Pawtucket Canal — Lowell — at Upper Side of Hamilton Footbridge to Blue Dye House. May 23, 1918,* P.M.

Station.	Depth. Feet.	Mean Velocity. Ft. per Sec.	Velocity. Ft. per Sec. 0.8 Depth.	Velocity. Ft. per Sec. 0.2 Depth.	Mean Ft. per Sec.	Ratio Mean of 0.8 and 0.2 Velocities to Mean Velocity in Per Cent.
3	9.1	3.40	2.81	3.71	3.26	95.9
10	11.3	3.77	3.09	4.85	3.97	105.3
17	11.2	5.06	5.00	4.78	4.89	96.6
27	11.9	5.29	6.00	4.48	5.24	99.0
36	12.0	5.79	5.00	6.31	5.66	97.7
45	11.6	5.21	4.60	5.77	5.18	99.4
54	11.6	5.23	4.90	5.52	5.21	99.6
63	11.6	4.56	4.00	4.96	4.48	98.2
72	11.3	4.00	3.30	4.70	4.00	100.0
81	9.0	3.86	3.30	4.52	3.91	101.3
90	6.7	3.48	3.22	3.56	3.39	97.4
95	5.4	2.97	2.87	3.06	2.97	100.0
		4.49			4.46	99.3

NOTE. — It is evident from an inspection of these results that while the actual velocity is usually but within a few per cent. of that obtained from the 0.2 and 0.8 method, there is no assurance that the latter method can be relied upon, and it is therefore better for each section to make complete traverses of velocities and a comparison in advance, leaving the 0.2 and 0.8 method for complete measurements at a later date. The committee will endeavor to have in the final report some comparisons between the two current meter methods and some rod float measurements in rectangular canals, which have been made in Lowell for a great many years.

* Not exact.

from the left side of the flume, one 6 ft., one $19\frac{1}{2}$ ft. and one 30 ft. up from the weir. The mean of 130 readings showed the right-hand hook gage 0.0075 ft. lower than the left-hand hook gage, and the average depth on the weir to be 2.2000 ft. At the same time six sets of measurements from nails to water surface gave 2.2173 ft. as the average depth on the weir, or 0.0173 ft. more than shown by the hook gage. A comparison was also made between the readings of the left-hand hook gage and the surface of the water at the different points from 6 to 30 ft. up from the weir. The water surface in every case was lower 6 ft. up from the weir than it was 10 ft. up, but both these points stood higher than the hook gage showed. Multi-point current meter measurements were also made at sections 6 ft. and 10 ft. up from the weir. The average velocity 10 ft. up from the weir, or at the hook-gage pipe, was found to be about 1.47 ft. per second; and with the holes (in the bottom and 3 ft. apart) at right angles to the current, the head is apparently held down about three-quarters as much as the head (0.03 ft.) required to get up this velocity. Had this point measurement been made simply at 0.2 and 0.8 depth, the resulting average velocity in the section would have appeared to be about 1.57 ft. per second, or nearly 7 per cent. too high. For the measurement 6 ft. up from the weir, the 0.2 and 0.8 method shows about 98.3 per cent. of the actual average velocity.

A very recent measurement showing the effect of an ice boom has been made in the Pawtucket Canal in Lowell at the upper side of the Hamilton footbridge. Four measurements have been made, on March 15, 22 and 29, 1918, with the boom in place, and on May 23, 1918, with the boom partly removed.

These measurements were multi-point measurements. Had the measurement of March 29 been made only at 0.2 and 0.8 depth, the resulting velocity would have been about two per cent. less than the actual average velocity in the section. Had the measurement of May 23 been made only at 0.2 and 0.8 depth, the resulting velocity would have been about one per cent. less than the actual velocity in the section.

On July 26 and August 5, 1910, some measurements made in the Lawrence Manufacturing Company (Lowell) Nos. 4, 5

and 6 raceways show the effect of a shallow power canal with a rough bottom and fast velocities. There is a very decided pulling back of the water at the *bottom* of the section.

If these measurements had been taken simply at 0.2 and 0.8 depth, the apparent average velocity would have seemed to be about 1.5 per cent. higher than the actual average velocity for the right-hand raceway and about right for the left-hand raceway.

Measurements were also made on the Lawrence Nos. 1, 2, 3 raceways on August 5, 1910. These raceways are much deeper at the center and about the same depth on the edges as the Nos. 4, 5, 6 raceways. Here the pulling-back effect in the center is not as noticeable, due to smoother bottoms and greater depth, but the effect is greater in the shallower parts. The 0.2 and 0.8 method gives results over two per cent. high for the outer sections, while it gives about the correct velocities for the center or deeper part of the canal.

The effect of pulling water out of a canal is shown in the measurement made October 5, 1911, at the entrance to the three feeders of the Bigelow Carpet Company, now the U. S. Cartridge Company, Lowell, Mass., plant. At the entrance to the left-hand feeder the 0.2 and 0.8 method showed over five per cent. higher than the actual average velocity, to the center feeder 1.5 per cent. and to the right-hand feeder 3.5 per cent.

PRECIPITATION, EVAPORATION AND RUN-OFF.*

Rain or snow falling on the drainage areas of rivers is the immediate source of run-off. The relation between the precipitation and the run-off is a direct one; rain falls on the ground and a part of it finds it ways to the water courses, and yet there are so many physical factors affecting the disposal of precipitation that to establish any exact relation between it and run-off is impossible. The cycle of precipitation and run-off is complete when we include the evaporation of moisture in the form of vapor from water and ground surfaces, to fall later as rain.

The U. S. Weather Bureau and private individuals have

* By Arthur T. Safford.

kept precipitation records at stations geographically widely distributed for a long period of time; and it frequently happens that good precipitation records are at hand when no stream gagings can be obtained. For this reason, any relation, even only approximately fixed, between precipitation and run-off is of considerable value to the engineer. Run-offs based upon a percentage of precipitation are only true of long-term averages and are to be used with the greatest caution. A dry year means one of low precipitation where the amount available for run-off is but a few inches; a wet year one when, with all natural requirements satisfied, there is a large balance for run-off.

The local variation of the average annual precipitation in the United States is all the way from nothing in some years in the desert regions to an occasional maximum of more than 100 ins. in the mountains of the extreme northwest. In general, mountain ranges receive a greater amount of precipitation than the surrounding valleys and yield a greater proportionate run-off. The lack of mountain records has kept this fact from being common knowledge.

The main factors affecting the disposal of precipitation are the topography, geology, evaporation and the amount taken up by vegetation. Rugged drainage areas with steep slopes discharge the water readily and quickly into the water courses. Rivers draining such areas, unless there is good storage in lakes and ponds, are more subject to sudden fluctuations in flow than rivers draining flat or rolling country where there are many swamps and where the water has chance to sink into the pervious soil. Evaporation, according to our best present knowledge, is essentially the same from year to year in any one locality but varies more or less regularly with the temperature of the water and wind; the amount of moisture taken by the vegetation is about a constant.

Precipitation records have been kept in a few places for long periods of time and yet they have not been collected and analyzed in any exhaustive way until recently. X. H. Goodnough, in a paper published by the New England Water Works Association in September, 1915, has collected rainfall statistics from all over New England from the earliest known, 1749, to

the date of writing his paper. Detailed consideration cannot be given here to the variation of precipitation over long periods of time; but mention must be made of the geographical distribution of rainfall in New England, and in other districts where adequate records are available.

* "The highest rainfall recorded at any place in New England is at the summit of Mt. Washington, where observations were made continuously from September, 1871 to 1887. The average rainfall during that period was 83.53 in. The lowest rainfall recorded in New England is that along the shores of Lake Champlain, where at Burlington, Vt., the average rainfall for a very long period of years has amounted to 32.76 in.

"It is evident from a consideration of the available records that the effect of elevation upon the rainfall is very marked, and it is probable that the higher rainfall in the mountainous districts has not hitherto always been adequately considered in studies of the flow of streams and yield of watersheds. Unfortunately, except at the summit of Mt. Washington, few rainfall stations have been maintained among the higher ranges either in the White Mountain region or the other mountainous regions of New England, so that it is impossible to ascertain definitely the extent of these areas of high rainfall. In the White Mountain region the very high rainfalls are very probably confined to the highest summits and diminish rapidly as lower levels are reached, though the records available show very clearly that the rainfall south and east of these mountains is higher than elsewhere in this region except on Mt. Washington. There are indications also that the rainfall in western Maine along the easterly slope of the extensive highlands west of the Kennebec River is higher than in the central and northern portions of the state.

"The rainfall at Bar Harbor at the eastern base of the mountains of Mt. Desert is much higher than elsewhere in this region, and it is possible that along the highlands toward the north of Bar Harbor and east of Bangor similar conditions obtain, but the available records are inadequate to show, except in a very general way, the variations in rainfall in that region.

"Aside from the higher rainfall of the mountainous districts, the highest precipitation in any large area in New England occurs in the southern portion of the district. This area of high rainfall extends from the neighborhood of the Croton watershed in New York, where the rainfall is higher than in adjacent portions of New England, across Connecticut, Rhode Island and

* Copied from X. H. Goodnough's paper on "Rainfall in New England, *Journal of the New England Water Works Association*, September, 1915, page 248.

parts of southeastern Massachusetts, nearly to the eastern coast of the latter state, the amount gradually diminishing as a rule from approximately 50 in. in western Connecticut to about 46 in. in southeastern Massachusetts."

This excess of precipitation due to high altitudes should not be lost sight of; the gathering ground of many of our best reservoir sites is made up of high rocky and wooded areas both well situated for a large run-off; if reservoirs are deep and of large capacity, the net result may be a very large part of the precipitation actually collected.

In the Catskill Mountains gages at the summits invariably show materially greater precipitations than in the valleys, the difference being as much as 15 ins.

The seasonable distribution of precipitation has marked effect on the proportionate part reaching the streams. Studies of precipitation and yield in different areas, where accurate records of precipitation and run-off have been kept, demonstrate that for the precipitation to reach the streams abundantly it must fall in the months from October to April inclusive and not from May to September, when growing crops take the greater part. A well-sustained summer flow is only possible where an excess of precipitation prevails.

The Mississippi valley, extending from the Gulf of Mexico to Canada, and from the Alleghanies to the Rocky Mountains, is shut in on the east by mountain ranges whose eastern and southern slopes receive most of the rain borne by easterly winds blowing off the Atlantic, and, robbed by the western slopes of the Rockies of most of the rain borne by westerly winds from the Pacific, the source of most of the rain falling over the Mississippi valley is to be sought in the Gulf of Mexico. Within this basin the southern extremity receives the heaviest precipitation while the extreme northwesterly portion, at the headwaters of the Missouri, receives but little more than one fifth the amount falling at the mouth of the river.

This is indicated by the following table, which shows that, independent of altitudes, there is a tendency for the greatest rainfall to fall near the coast, and gradually to decrease as the wind currents travel inland.

	Average Annual Precipitation. Ins.
New Orleans	60
Memphis	52
Cincinnati	42
Pittsburgh	36
St. Louis	40
Headwaters upper Mississippi	25
Headwaters upper Missouri	13

Precipitation is the only source of run-off; evaporation is, after vegetation, the chief agency reducing the available supply of water running off in the rain-water courses. Wherever there is storage of water in natural ponds or artificial reservoirs, the effect of evaporation from water surface must be considered; and in some cases, which the irrigation projects typify, evaporation from the soil must be considered as well.

TABLE 2.

EVAPORATION IN INCHES FROM WATER SURFACE AT CERTAIN LOCALITIES IN MASSACHUSETTS, MAINE, CALIFORNIA, NEVADA AND OKLAHOMA, BY MONTHS.

	Chestnut Hill, Boston, Mass. Inches.	Maine Composite Figures. Inches.	Lake Tahoe, California, 1901. Inches.	Sweetwater Reservoir, California. Mean 1910–14. Inches.	Reno, Nevada, 1901. (Seven months only.) Inches.	Lake Lawtenka, Oklahoma. Mean 1913–15. Inches.
January	0.96	0.7	0.84	2.56	....	1.665
February	1.05	0.7	0.70	2.56	....	1.825
March	1.70	1.1	0.77	2.73	....	3.42
April	2.97	1.6	1.25	4.08	....	4.38
May	4.46	2.1	2.42	6.09	2.80	6.11
June	5.54	2.8	3.35	6.74	5.35	7.90
July	5.98	4.32	4.00	8.80	8.45	10.04
August	5.50	5.0	6.50	7.45	9.12	9.24
September	4.12	3.32	4.12	6.62	7.44	6.845
October	3.16	2.2	2.65	5.06	4.31	4.25
November	2.35	1.3	2.09	3.11	2.75	1.98
December	1.51	0.7	1.44	2.18	....	1.23
The year	39.20	25.84	30.13	56.98	40.22*	58.895

* Evaporation at Reno, Nev., from May to November inclusive, slightly exceeds the total evaporation for the year at Chestnut Hill, Boston, Mass.

Records taken in various parts of the country make it possible to take account intelligently of the amount of loss due to evaporation in the neighborhood of the observation station; but so many variable factors of climate and elevation affect the result that records in one part of the country cannot safely be applied to a remote section.

The best-known experiments are those of Desmond FitzGerald at the Chestnut Hill Reservoir, in Boston, Mass., but other experiments and observers in other parts of the country have in recent years been increasing the fund of information.

The best records at this time known to the writer are given in Table 2.

In connection with the Sweetwater experiments, observations indicate that for a given mean monthly temperature the amount of evaporation increases with the elevation above sea level.

Table 3 gives the total annual evaporation for 17 stations in Texas, New Mexico and Oklahoma.

Experiments at Chestnut Hill and other stations indicate that each 9 degrees Fahr. of change in water temperature corresponds to about 1 in. per month change in the amount of evaporation.

For a water-storage proposition, the best conditions for a large net yield are:

1. A high collecting ground near one of the oceans or the Great Lakes.

2. A drainage area large enough to fill the reservoir, almost every year.

3. A deep reservoir and one of small evaporation surface.

4. A high altitude.

(1) and (2) will control the inflow; (3) and (4) the outflow.

The large lake or pond with small drainage area which has no outlet is usually simply a body of water which has no compensating yield to offset the evaporation.

Distribution of run-off: For comparative purposes it is convenient and advantageous to express the flow of rivers not by total flow, but in second-feet per square mile of drainage area.

TABLE 3.

EVAPORATION, TEMPERATURE AND ELEVATION.
TEXAS, NEW MEXICO AND OKLAHOMA.

Place.	Date.	Elevation. Feet.	Evaporation. Inches.	Temperature.
Galveston, Tex.	July, 1887 — June, 1888	6	46.0	68.7
Corpus Christi, Tex.	July, 1887 — June, 1888	20	38.8	69.4
Brownsville, Tex.	July, 1887 — June, 1888	50	37.0	71.0
Rio Grande City, Tex.	July, 1887 — June, 1888	230	53.1	71.4
Palestine, Tex.	July, 1887 — June, 1888	500	47.1	64.1
Austin, Tex.	Jan. — Dec., 1911	600	50.92	69.2
San Antonio, Tex.	July, 1887 — June, 1888	700	52.4	66.8
Lake Lawtonka, Okla.	April, 1913 — Mar., 1914	1,200	60.38	61.2
Lake Lawtonka, Okla.	April, 1914 — Mar., 1915	1,200	55.78	59.4
Abilene, Tex.	July, 1887 — June, 1888	1,740	54.4	62.1
Carlsbad, N. Mex.	Jan. — Dec., 1899	3,000	54.37	63.1
Carlsbad, N. Mex.	Jan. — Dec., 1901	3,000	43.26	64.1
Lake Avalon, N. Mex.	July, 1909 — June, 1910	3,200	94.51	63.8
El Paso, Tex.	Sept., 1889 — Aug., 1890	3,700	81.5	64.8
El Paso, Tex.	June, 1889 — May, 1890	3,700	84.3	65.7
El Paso, Tex.	July, 1887 — June, 1888	3,762	82.0	63.6
Elephant Butte, N. Mex.	July, 1909 — June, 1910	4,250	86.95	61.1
Port Davis, Tex.	July, 1887 — June, 1888	4,930	91.4	59.7
Albuquerque, N. Mex.	Feb., 1900 — Jan., 1901	5,000	77.87	56.5
Albuquerque, N. Mex.	Jan. — Dec., 1903	5,000	87.90	54.1
Fort Stanton, N. Mex.	July, 1887 — June, 1888	6,150	77.0	50.0
Santa Fé, N. Mex.	May, 1913 — April, 1914	6,900	58.92	48.9
Santa Fé, N. Mex.	July, 1887 — June, 1888	7,013	79.8	48.9

The following is a list of the major factors influencing the distribution of run-offs.

(*a*) Geology — is the soil pervious or impervious?

(*b*) Topography—is the drainage area flat or rolling, or has it steep, precipitous slopes?

(*c*) Size — of the contributing area.

(*d*) Climate — amount and distribution of rainfall and evaporation.

(*e*) Storage — whether natural or developed, the degree of development and the location of the storage basins.

(*f*) Forest cover — extent and character.

These cannot be said to be of equal importance, and the relative effect will differ on different areas. The fifth (*e*) and sixth (*f*) factors only can be varied by man; and, looked at in this light, they assume an importance of greater moment than the rest. An even distribution of run-off is a most desirable characteristic.

Taking up in order the main factors, we shall see how each one affects the distribution.

Pervious soil will allow the water falling on it to percolate down into it, where it is held as ground water, a part to find its way into the streams when the general water table is lowered. If the soil is impervious, water must run off quickly and find its way into the water courses. Thus heavy storms of short duration falling on frozen or saturated ground will cause sudden rises in the streams, and much water may be wasted. On our large rivers the run-off in a few weeks may be greater than that of the entire dry period of six months.

Flat or rolling country combined with a pervious soil is admirably fitted to hold the rain in storage as ground water. The precipitous rocky slopes are equally fitted to discharge the rain almost as it falls and do nothing to even up the distribution of run-off. But if complete or nearly complete water storage is provided, a precipitous drainage area may be better for water-storage purposes than more level country. Between the two conditions are a multiplicity of possible combinations and effects.

The size of drainage area has an additional, sometimes a controlling, influence when there is little or no storage available. This is because the variation in the extent and intensity of rain storms is extreme. A local storm of sufficient intensity to cause a freshet on a small area, occurring on a drainage area of a thousand square miles or more, would hardly be felt on the main river but it may help to keep up the flow of the larger area. It is for this reason that, without storage, small rivers show much greater divergence between maximum and minimum discharge than large rivers.

This would to some extent be offset by a complete forest cover, which on the small stream would undoubtedly delay the

peak of the flood and might entirely prevent a sudden rise, and certainly detains the last of the snow and ice for at least a month. It can never, however, hold the water in storage like a reservoir, to be let down at certain seasons of the year. Furthermore, on drainage areas of considerable size, sufficient areas usually cannot be deforested or grow up fast enough to have a more than local effect.

The climate prevailing on a drainage area will depend on its geographical location and on its topography. It is sufficient to refer here to but two aspects, — (*a*) the total annual precipitation and its distribution; (*b*) the total evaporation and its distribution. There is such radical variation in different parts of the country that every case must receive careful study to ascertain the local conditions and tendencies.

Typical hydrographs showing the monthly average stream flow in second-feet per square mile of drainage area naturally exhibit different characteristics according to the local climatic and other conditions. Furthermore, the hydrographs of the same river vary materially from year to year, between rather wide limits.

Experience has shown that, without large water storage, water-power streams cannot be trusted to turn out a given product in any one year; and the breaking-in process of a large development without storage may severely tax the patience and ingenuity of the man operating such a plant.

THE EFFECTS OF ICE ON RIVER DISCHARGE.*

Rivers may in general be divided into two classes: (*a*) those having deep channels with surfaces for considerable distances unbroken by falls or rapids and which are similar to canals in their flow characteristics, and may be called the "canal" type; and (*b*) those having irregular channels with frequent changes in slope, together with numerous riffles, rapids and waterfalls, which may be called the " cascade " type. Naturally the same stream may change from one type to the other in different

* By C. H. Pierce.

parts of its course, and the two types may merge so that deep, still sections of the river may be immediately followed by rapids and falls.

With respect to physical requirements for suitable current meter gaging stations, all rivers may be said to fall between the limiting cases of (1) the canal, with no definite control section, the stage-discharge relation depending upon the slope of the canal, the shape of its cross-section, and the roughness of the sides and bottom, according to the generally accepted formulas of $q=av$, and $v=c\sqrt{rs}$; and (2) the weir, with the water flowing over a well-defined crest or control, for which the discharge may be represented by an equation in the form of $q=clh^n$.

Although the natural stream may never exactly fulfill the theoretical requirements whereby the flow can be accurately computed by either of the above methods, yet for the purpose of this discussion they may be considered as limiting cases, which may be sometimes approximated, and it may be ascertained if in those cases it is possible to deduce any general laws applicable to the effect of ice cover.

Surface ice will be considered first, and then anchor ice, frazil ice, and the occurrence of one or both in conjunction with surface water.

In the case of the canal with surface ice cover, with gage heights read to the water surface, the effect of ice is to decrease the effective area or cross-section for a certain gage height and to increase the frictional resistance, since the wetted perimeter p is increased by an amount equal to the surface width.

For a certain discharge Q, the depth of water or gage height is H, the width of stream is w, and the wetted perimeter is p. As soon as the stage-discharge relation is affected by the formation of ice there will be, for the same discharge, Q, a greater depth H_1 and a greater wetted perimeter p_1+w (Fig. 1), and it may be shown mathematically that the following relation exists:

$$\left[\frac{f\,H_1}{f\,H}\right]^x = \frac{p_1+w}{p}.$$

Whereby it may be seen that, theoretically, when complete ice cover is once formed there is an immediate increase in the gage height from H to H_1, corresponding to the increase in the wetted perimeter from p to p_1+w, but that, after the quantity w is once introduced into the equation, slight increases to the numerator p_1+w require only small increments to the difference between H_1 and H, since the left-hand member of the equation is to be raised to the x power where x is greater than unity. Therefore the resulting locus of the plotting of H_1 is a curve always above the curve of H and also always above a curve parallel to the curve of H but approaching this parallel curve as a limit at

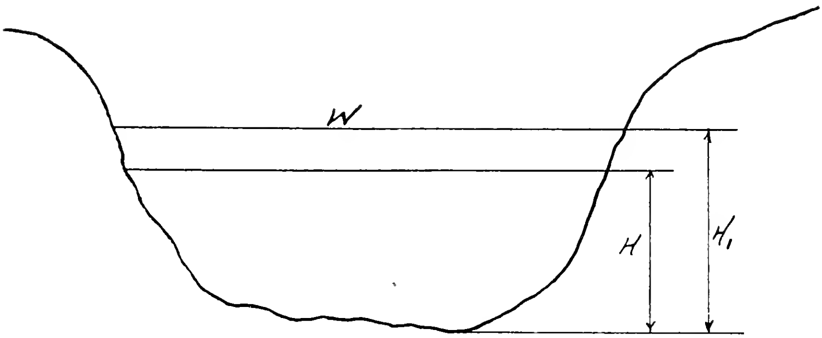

FIG. 1.

an always varying distance from the curve of H. Fig. 2 represents the locus of H_1 as it varies with the stage, but with ice conditions remaining the same. For every different set of ice conditions the locus of H_1 would be a different curve, and at varying distances above the "parallel" curve. There is no one curve which would represent the locus of H_1 under the varying ice conditions occurring during the winter, and therefore there is no one curve which can be properly used as a "winter rating curve" when the stage-discharge relation is affected by ice.

In the case of a weir section, or the control section of a stream of the cascade type, the disturbing effect of ice will occur when ice forms on the control irrespective of whether or not the stream may have ice cover, except that if there is ice cover in

addition to ice on the control, the backwater effect will be a resultant due to the two causes.

It is difficult to show mathematically how the backwater varies with the stage for stations having a weir control, but it is self-evident that, so long as the ice remains frozen on to the control, the backwater effect will increase up to the point where the ice is completely covered and overflowed, then the locus of H_1 will approach the "parallel curve" as its limit. With ice conditions continually varying, the backwater will also vary,

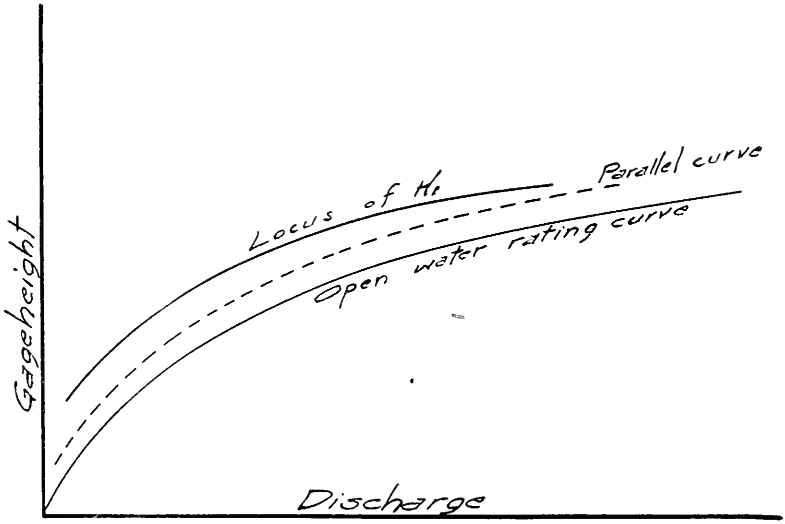

FIG. 2.

and the only way it can be determined is from the results of discharge measurements.

Anchor ice and frazil, although occurring from entirely different causes and differing in their methods of formation and appearance, have similar effects on river discharge. The term "slush" ice is commonly applied to both, for the reason that they form a "slushy" mass in the water, the "slush" usually being carried along by the current and frequently collecting in an almost impenetrable mass when the slower velocity has permitted the formation of surface ice.

Although neither anchor ice nor frazil actually form under the cover of surface ice, yet if the temperature is low enough to permit of their formation there is almost certain to be more or less surface ice in places along the stream; only under exceptional conditions of swift, turbulent water, or in canals below gates where a considerable loss of head occurs, would "slush" ice be found without there being also some surface ice. (It should be noted here that both of these conditions are unsuitable for the location of a gaging station.) It is, therefore, generally necessary to deal with "slush" ice in conjunction with surface ice, and it may readily be seen that, with the uncertainties incident to the method of formation and collection of this impediment to the flow, there can be no fixed mathematical relation between the open-water rating curve and the discharge with the channel partially filled with "slush" ice in addition to a more or less complete surface cover. The only mathematical certainty is that the discharge for a certain gage height, with ice in the stream, will always be less than the discharge for the same gage height, with the stream free from ice.

Any method for the successful determination of the river discharge after the formation of ice must be based upon frequent discharge measurement as control points, and some method of filling in between these points. Since the temperature and precipitation, also character of precipitation, whether rain or snow, are essential factors in connection with the formation and change of formation of ice, and also of the amount of run-off to be expected, a study of these data is helpful in connection with the use of discharge measurements.

Method of Determining Daily Discharge at Gaging Stations where the Stage-Discharge Relation is Affected by Ice.

1. Develop an open-water rating curve from measurements at different stages under normal conditions.

This is No. 0 curve in Plate I.

2. From the results of measurements when the stage-discharge relation is affected by ice determine the average curve for these conditions.

This is the No. 10 curve in Plate I.

PLATE I.
(Fig. 3.)
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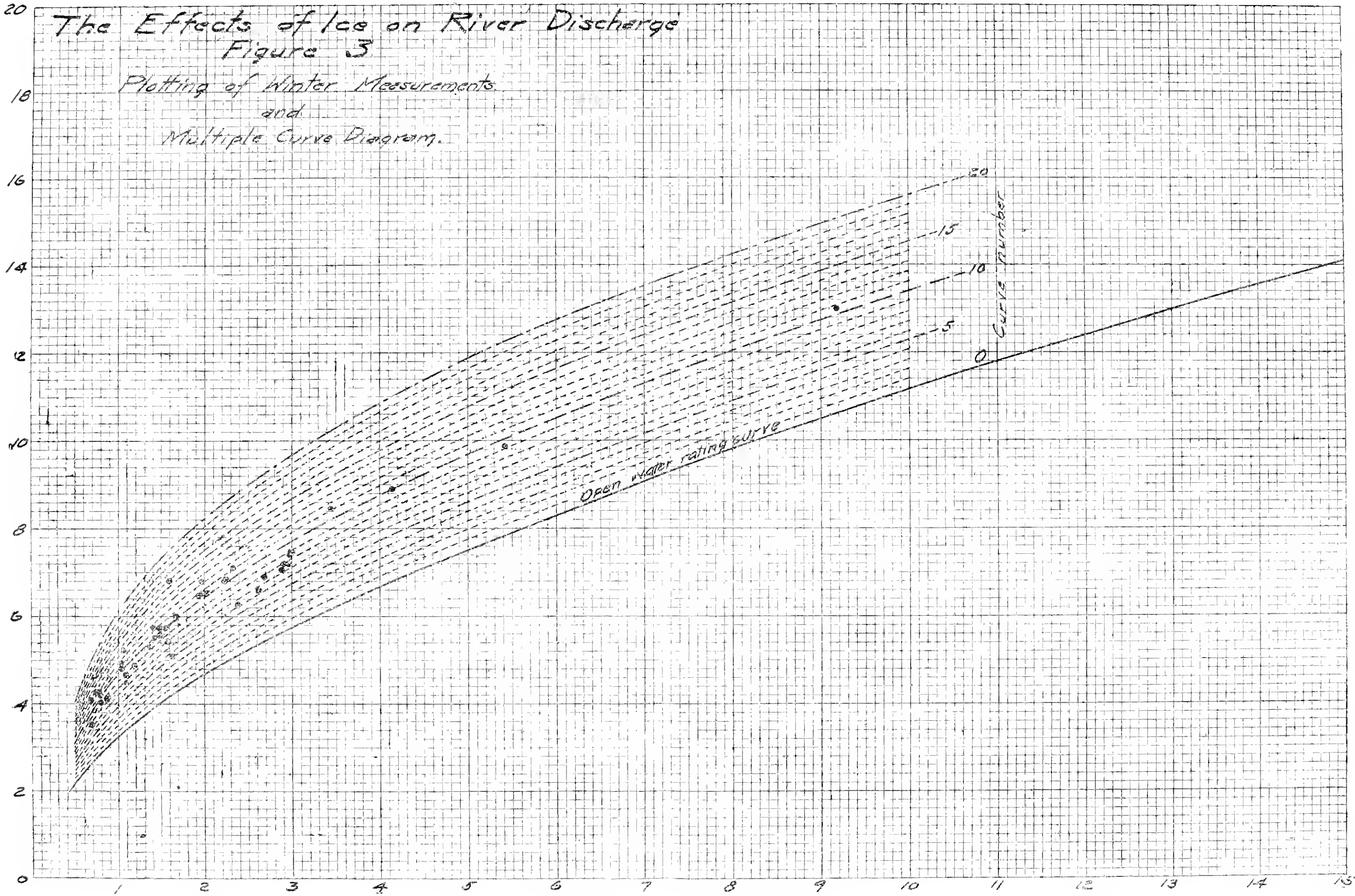
NOVEMBER, 1918.
COMMITTEE ON
RUN-OFF.



Gage height in feet.

Discharge in second-feet x 1000

PLATE II.
(Fig. 4.)
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RUN-OFF.

PLATE III.
(Fig. 5.)
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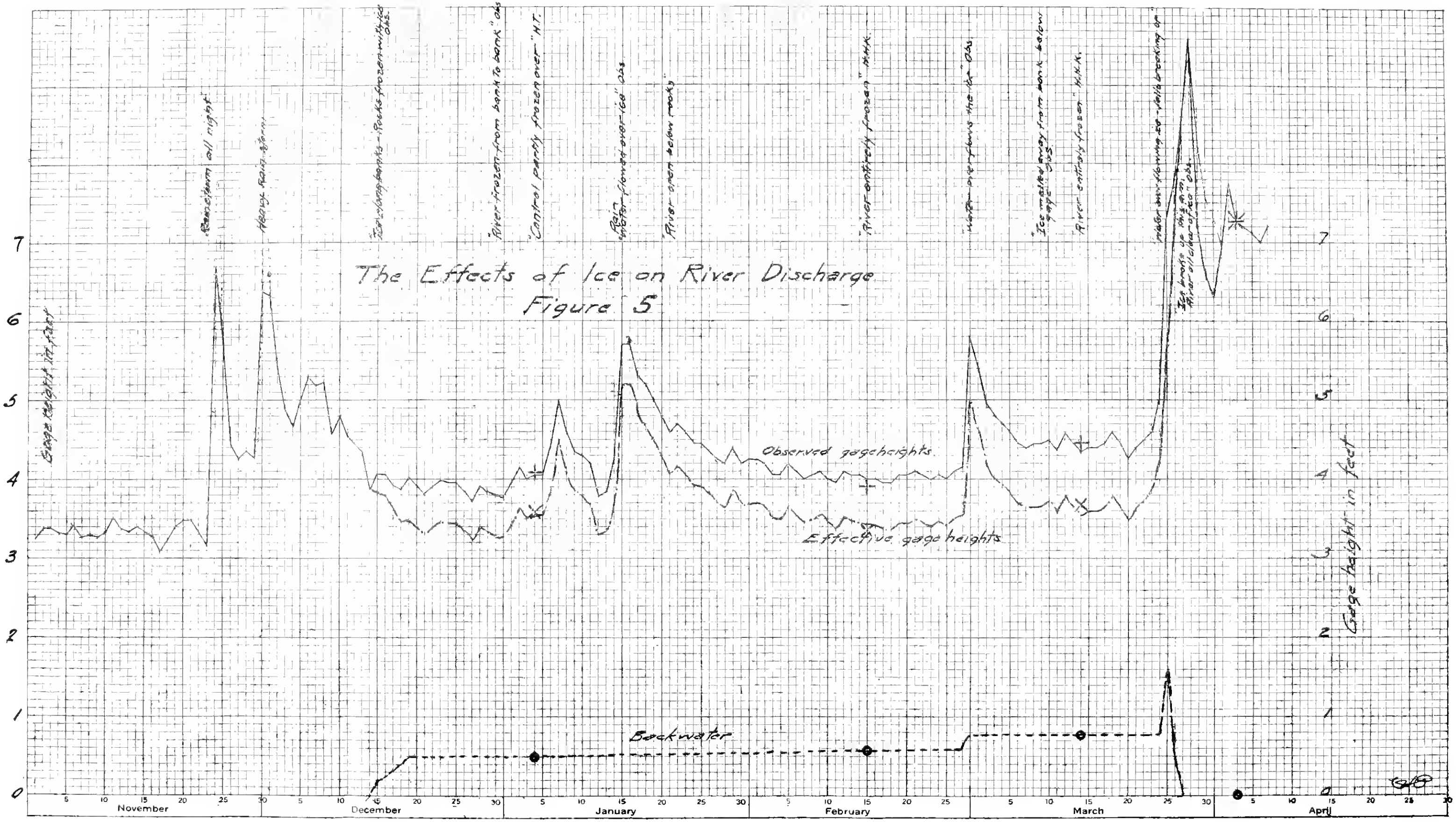
OF CIVIL ENGINEERS.
NOVEMBER, 1918.
COMMITTEE ON
RUN-OFF.



3. Interpolate curves 1 to 9 and exterpolate curves 11 to 20.

4. Ascertain as nearly as possible the date when stage-discharge relation was first affected by ice, and the date when the use of curve No. 0 should cease. This gives point "a" at the beginning of diagram, Plate II.

5. Plot each discharge measurement made during the winter on multiple curve diagram (Plate I), and ascertain thereby the number of the rating curve which is applicable at that time.

6. Plot points corresponding to their numbers, as "b," "c," "d," etc., on diagram, Plate II.

7. Join points a, b, c, d, etc., so that by interpolation the number of the curve to be used on any day may be found.

8. Knowing the number of rating curve and the mean gage height for the day, take out the corresponding daily discharge from the multiple curve diagram or from tables based on the diagram.

The above method is rather tedious, inasmuch as it involves the use of a number of different rating curves or rating tables. If, however, we may assume that the multiple curves are parallel for short portions of their length so that each measurement may be referred to curve No. 0 and a correction to be applied to the mean daily gage height for that day be determined, then by plotting these corrections as ordinates (Plate III) and filling in between the plotted points, either by straight interpolation or, better, by taking into consideration the factors which might influence the corrections, such as temperature, precipitation, description of ice conditions, etc., corrections are obtained which when applied to the observed daily gage heights (Plate III) give the corrected or "effective" daily gage heights (Plate III) to which the rating table may be applied to obtain daily discharge.

This method is the practical application of the theoretical method first described, and is the one which has been generally used by engineers of the U. S. Geological Survey for several years. Numerous studies and comparisons indicate that the results of this method are much more reliable than those obtained by other methods formerly in use.

METHODS TO BE USED IN COMPILATION OF DATA. ANALYSIS OF RUN-OFF RECORDS.*

It will be here assumed that the run-off records will be in the customary form, used by the U. S. Geological Survey, of daily discharge and also of weekly, monthly and annual summaries, the latter giving the maximum and minimum daily discharge, the average for each month, the corresponding second-feet per square mile and run-off depth in inches for each month, and a final summary of the same data for the entire year.

1. Since most hydraulic engineers are now familiar with and extensively use the "daily duration curve," it is suggested that such curves, including the average and "enveloping" curves, be prepared for each gaging station analyzed, covering the entire period of record, the results being presented in both tabular and graphical form.†

If it seems desirable to present all of the curves on one drawing, only the longest term stations should be thus compared, and the duration curves should be for the same period of time.

Attention should be called to the method of preparing duration curves. A duration curve is computed by tabulating the number of days "equal to or greater than" a given rate of flow, and this is exactly opposite to the "deficiency" table or curve which is obtained by tabulating the number of days "less than" a given rate of flow. Thus a duration table (or curve) may be directly obtained from a deficiency table (or curve) by subtracting the number of days corresponding to each rate of flow from the total number of days in the year or entire period.

2. Since a duration curve for a year or longer does not indicate the monthly distribution of flow, and since the latter is a requirement in relay studies, and since furthermore it is just as easy to tabulate the original computations by months and total for the years and period, it is suggested that a secondary summary table (and perhaps curves) be given, indicating the total duration of flow, month by month, for the period of record.

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* By C. H. Pierce.

† For purposes of ready comparison, these curves should be plotted per cent. of time against second-feet per square mile. Arithlog paper is suggested.

3. From the foregoing two summaries, additional tables (or curves) should be prepared, indicating, for each five per cent. of the time, the ratio of the computed to the average rate of flow for the period, either for each year or the total period, or both. For a discussion of this theory see "Power Estimates from Stream Flow and Rainfall Data," by D. M. Wood, in the JOURNAL OF THE BOSTON SOCIETY OF CIVIL ENGINEERS for March and June, 1916, — especially the latter; also "Comparison of New England Run-off Data," by D. M. Wood, in *S. & W. Public Service Journal* for February, 1917. Comparisons by this method should be for the same period of years.

4. For general comparison of records, it may be helpful to present a diagram showing the total depth in inches of run-off, year by year, for each station analyzed, an example of which method was presented some time ago to the entire committee by Mr. Pierce.

5. Many engineers like to divide the year into the storage, growing and replenishing seasons, and, as a corollary to No. 4, the depth in inches of run-off might be shown by seasons as well as by years. If so, it is suggested that the year be divided December to May, June to August, and September to November, as best applicable to New England.

6. Perhaps no analysis would be complete without some form of river characteristic curve indicating the benefits of storage. If such is to be included in our report, only natural run-off records (i. e., records from which the effect of existing storage has been eliminated) should be used. By computing a mass curve for the driest period of record, a characteristic curve, plotting "required storage" against "minimum regulated flow," can be obtained. If this is done, attention should be called to the fact that it presupposes that the storage will be operated for the purpose of obtaining the greatest primary flow possible, and does not take into account benefits derived from operating the storage each year to the fullest extent possible. In other words, it treats of only one of the two general methods of operating a storage reservoir.

7. As an alternative to No. 6 it may be deemed useful to present a tabular comparison by stations of minimum consecu-

tive periods, such as week, two weeks, three weeks, month, two months, etc., up to six months.

It might be suggested that the simple "old-fashioned" hydrograph, obtained by plotting consecutive values of daily discharge, represents more truly than any other method the actual run-off conditions.

8. It might prove interesting to tabulate for a large number of power plants in New England the installed capacity per square mile of drainage area per foot fall of effective head, i. e., unit capacity installed. This would serve to bring out the large variation in practice. The tabulation might well be grouped by plant types.

9. Some analysis should be given of the studies made of winter conditions, both as regards (1) snow storage and (2) the effects of ice on stream-gaging records. As these problems are being treated by special subcommittees, no suggestions are made by this committee.

10. For the treatment of "pondage," attention is called to two methods covered in current literature, the second really being adapted from and suggested by the first:

(1) Chas. T. Main's method, as given in *Journal of New England Water Works Association*, Vol. 21, p. 214.

(2) D. M. Wood's method, as given in JOURNAL OF BOSTON SOCIETY OF CIVIL ENGINEERS, Vol. 3, p. 99.

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BOSTON SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

THE ORIGIN OF CAMP BROOKS AND THE OPEN-AIR TREATMENT OF INFLUENZA.

By Lieut.-Col. William A. Brooks, Chief Surgeon, M.S.G.*

(Presented before the Sanitary Section, November 15, 1918.)

For a man who has devoted most of his professional life to surgery and the study of surgical problems I feel out of place in addressing the Sanitary Section of the Boston Society of Civil Engineers.

The open-air treatment was forced upon me and upon my friends, members of the medical corps of the State Guard.

The origin of the first camp hospital (Fig. 1) was due to the fact that some little time ago I had accepted the position of medical director of the recruiting service of the Shipping Board. We had organized a good corps of doctors, and everything went well until there came a rumor of influenza. There was some in Russia and some in this country, and in talking it over with Dr. Croke, the medical officer in charge at East Boston, I told him to be on his guard against it, and if he found a case to insist that everything coming in contact with that patient be disinfected and that the nurse in attendance wear a mask. At that time we had gathered together on the ships between 5 000 and 6 000 men.

One Friday morning Dr. Croke telephoned me that he

* Brooks Hospital, Corey Hill, Brookline, Mass.

thought he had one or two cases of influenza, and we again talked over precautions to be taken in regard to it. On the following Monday morning he telephoned me that he thought they were all getting sick, so I went over to East Boston and through some of the ships, and found many men stricken and lying on the decks and in their bunks. My first impulse was to get away as soon as possible — and I followed that impulse. I went to Boston and saw Mr. Howard, director of the Shipping Board, and told him of the situation, and he asked me what I would

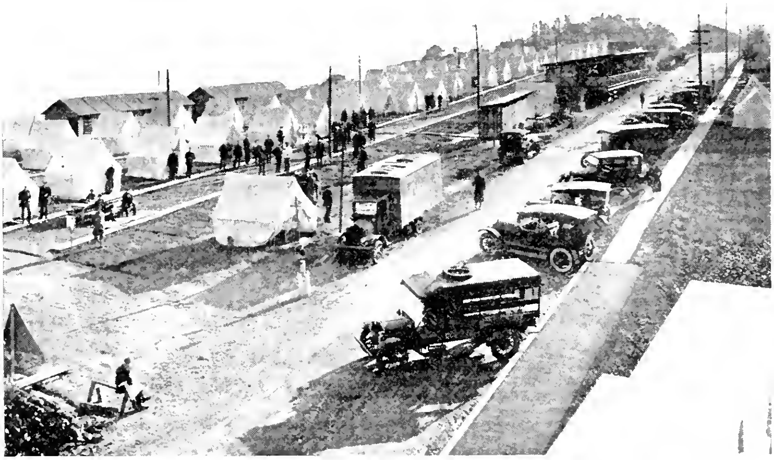

FIG. 1. FIRST CAMP HOSPITAL AT COREY HILL, BROOKLINE, MASS.

advise. I said, if possible, make arrangements with the state authorities and establish a camp hospital. I knew that the hospitals in Boston at that time were pretty well congested, and did not see how we could possibly place as many sick persons as we had. Having obtained Mr. Howard's consent to the plan, I conferred with the Adjutant-General, telling him that the Shipping Board would pay the expense, whereupon he ordered out the State Guard. At 2.30 o'clock in the afternoon, Colonel Emery, quartermaster-general of the state of Massachusetts, received instructions to send tents and supplies to Corey Hill,

and at the same time I ordered out the Medical Corps. That night, about 5.30 o'clock, the tents arrived, and before midnight we had them erected, sewerage connections made, and the water supply turned on. By 12.30 A.M. there were 38 patients in tents, and from that time the camp grew very rapidly, the problems increasing as fast as the camp grew. We had some very bad weather for three or four days, and then we commenced to get deaths. We tried everything we knew of, and felt very much discouraged. At the meetings of the medical staff, we concluded

FIG. 2. SHOWING HOW PATIENTS WERE PLACED IN THE OPEN AIR.

we had struck something serious, but we did not know exactly what, as ordinary remedies did not seem to affect the patients favorably. Combined with the wet weather the situation was extremely depressing. Dr. Slack and Dr. Overlander made some studies and, as Dr. Harrington will tell you, they found that there was a mixed infection including many kinds of bacilli; the bacillus of influenza, at least three types of pneumococci, the streptococci, and later the diplicocci. I can only compare the situation to that of a man who takes two or three cocktails

before dinner, several kinds of wine with his dinner, and after it a cordial, and then drinks Scotch and soda all the evening.

However, we soon began to get some light. A report from post-mortem examinations from the Naval Hospital stated that they found the men died because they couldn't get enough air, and the physicians reported the finding of abscesses in the lungs. They also found most of the hearts normal. Then Dr. Harrington found that the worst cases came from the holds in the ships where the air was the poorest. One case I have in mind, who came from the hold of one of the ships, died two or three hours after reaching camp.

After observing these facts, the problem was comparatively simple. We just put the patients out in the open (Fig. 2), where they could get all the air there was. The night of the first day after we had put the patients out into the open, we found, almost without exception, that they had lower temperatures than they had had in the morning, showing most decidedly the effect of plenty of fresh air and sunshine. We took courage, and whenever we could we put the patient out into the air. I think the results justify the treatment.

We met with all kinds of opposition and criticisms. One of the leading physicians of Boston made complaint to the State Board of Health that we were abusing our nurses and treating our patients cruelly. The State Board of Health investigated and found no ground for the complaint.

One morning, after a very stormy night, I was called up by a gentleman who said that he wanted to tell me I was the most cruel man in the world because I had kept those boys out in the cold and rain, and that I ought to be shot, or something to that effect. Although I invited him to put on his coat and come up and look the camp over, I have never seen him and do not even know who he is.

The tents were so well ditched that they were dry, and the boys were extremely comfortable in them. The only ones who really suffered were the doctors and nurses, who were obliged to go from tent to tent in all sorts of weather, attending to the patients.

As soon as we found out what the fresh air really did for

our patients, as I have said before, we took courage and followed this course of treatment for five or six weeks.

A Comparison of Results.

One Sunday I walked into a general hospital of a city where there was a question whether it would be advisable to establish a tent hospital, and where they had eighteen or twenty in one ward, and was informed by the physician in charge that their patients were doing very nicely. He said they had only had four deaths the night before. I saw a number of young ladies going in as volunteer nurses and was invited into the ward. I thanked them, but firmly declined the pleasure. That was on Sunday. On the following Wednesday I went to this same city and was informed that in three days 20 of the patients in this hospital had died and 17 of the nurses were down sick. Now compare for a moment that record with the record of the most successful tent hospital we had, — that at Barre, Mass., — where cases were sent in early. We treated there 114 cases and had but 4 deaths. I could make many more comparisons where cases were just crowded together, eighteen or twenty in one room, and where they were treated out of doors in tents or shacks, and I think the comparison would be most satisfactory from my standpoint. As a matter of fact, the death rate ranged from 30 per cent. to 50 per cent. for indoor treatment in most hospitals, while out of doors our highest death rate was 18 per cent.

One thing which mitigated against our percentages was the fact that a great many physicians who did not believe in the treatment would send in patients as a last resort. They would keep them until they were nearly dead and then send them to the tent hospital. The records show that a great many of the cases accepted died within forty-eight hours after admission. This was not giving the open-air treatment a fair show.

To go back to the history of the first tent hospital. Out of between 5 000 and 6 000 men on the ships, we had some 1 200 cases of influenza. Out of the 1 200, we treated 351 of the worst cases, and of this number 35 died.

Masks.

The use of masks is based upon Rosenthal's experiment of making a solution of the "bugs" and allowing it to run through ordinary filter paper. The fluid which comes through is perfectly free from bugs; in other words, you cannot get cultures from it. To filter the air is the reason for wearing masks. Layers of gauze have been taken from masks which have been used near the patients, and bacilli have been found on them. In working around the patients, after two or three hours, the gauze becomes infected and consequently has to be changed. Rosenthal himself, in working over bacilli for hours at a time, only takes the precaution of wearing a wire mask covered with several layers of gauze, and after working washes his hands in a 1/1000 solution of corrosive sublimate, or triple lysol. He has clearly demonstrated that any one who takes these precautions can avoid contagion.

Ground for Objection to Treating Influenza in Wards.

Why should cases of influenza be separated from each other, and what is the safe distance? I have been told of a series of experiments conducted at the Massachusetts Institute of Technology where the lecturer placed in front of him agar plates in series up to 8 ft. and then filled his mouth with a harmless collection of "bugs." He delivered his lecture — talked, yelled and spoke as loudly as he could. At the end of his lecture the agar plates were developed and, as I remember it, growth was obtained up to a distance of 6 ft. — which would be approximately the distance a man might drive droplets. Therefore the safe distance for one patient to be from another would be about 7 ft. A ward of 20 beds would require a very large room, and still the nurses would be seriously exposed. In some schools it was observed that where one child would come suffering from influenza there would in a few days be an adjacent vacant area around that child's desk, showing that the nearest ones had become infected. This is, I think, one of the best reasons for closing the schools during an epidemic such as we have just been through.

But what I should like to know is, Why does the farmer, out in the country, who is not within a mile of a droplet, who hasn't been into town for months, come down with influenza? I'd also like to know why at sea, after the ship has been out six or seven days, men will come down with influenza? Why does it travel from east to west? Why does it go to sleep for a whole year and then wake up again in the fall? As for this particular epidemic, I should like to know why we get such a mixture of organisms, which made it so especially serious. These are the questions which ought to be answered. Has the climatic condition much to do with it? Why should such an epidemic as we have had suddenly spring up in one place and then move on to the next and reach its height in from ten to fifteen days?

The period of incubation is about two days, and yet it has traveled across the continent very quickly. So there still remain a great many problems about an epidemic of this kind, which will need a great deal of study in order to make them understood. Arguing from what has happened in the past, we shall probably have, next fall, another epidemic similar to this but not as severe, and the next year another but still lighter one. We learned that out of twenty men examined, one was a carrier. Now, if he is a carrier, why does he not continue to transmit the disease right along? Why does he wait until the next fall? These questions greatly puzzle one.

Of one thing I am convinced, — that hospital wards are not the places for the treatment of influenza. Up to the time that I went into the study of this big epidemic, I believed in the big hospitals. I believed that the wards were fine. To-day I am convinced that wards in hospitals are absolutely dangerous for diseases of the respiratory tract, and that they should be done away with. I am not sure that this is not true of other diseases besides influenza and pneumonia. We are coming to a time when our infectious diseases will be treated with not more than two patients in one room. If one man develops something very serious with another patient in the room, it is bad enough to move one, whereas if you have a room with twenty patients it is far worse to move nineteen.

One bad thing about the tent hospital is that the space at the top becomes foul, and there is no way of introducing ventilation there, and also the doctors and nurses are tremendously exposed in passing from tent to tent. Therefore I thought of cubicles 9 ft. by 9 ft., facing south, with a passage on the north side that would be heated. Here the attendants would not be exposed. The fronts of the cubicles can be made so that they can be opened out and the beds slipped out on to the ground or on to a platform.

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PAPERS AND DISCUSSIONS

THE INFLUENZA PANDEMIC — CAUSE, PREVENTIVE MEASURES AND MEDICAL TREATMENT.

By Major Thomas F. Harrington, Chief Medical Officer, M.C., M.S.G.*

(Presented before the Sanitary Section, November 15, 1918.)

I am glad your presiding officer said I would tell you what is known about this disease, because that would take so much less time than to attempt to tell what we do not know about it. It would be a tiresome and discouraging story to tell the things which we do not know to-day, even after our great experience of the past two months or so. Historically, influenza is very old. There are well-authenticated data of pandemics of influenza going back into the fifteenth and sixteenth centuries. The present pandemic is the fifth within one hundred years. There was one in 1830–33, another in 1836–37, a third in 1847–48, and one comparatively recently which most of you will remember, — in 1888–89. A peculiar coincidence is that in most previous epidemics it was called cholera or plague. In the history of the town of Boston, a good description of the present epidemic of grippe, under the name of cholera, shows that at that time (1830–33) they recognized the contagious and infectious nature of this disease, but it was linked up with the story

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of the great pestilences and great waves of destruction of life that have come down to us from very ancient times. It is a curious coincidence that in most pandemics the trouble has started in the Far East. The recent epidemic of 1888–89 reached Moscow in the spring of 1889; in the summer it reached Petrograd; then Berlin; then London and Paris; and we received it about Christmas time of that year — which some of you may remember. It is a peculiar fact that in all the discussion and doubt about the present epidemic we seem to have lost sight of some very important facts. So far as the censorship allowed, we have read that the armies of Europe were being attacked during the past year by a peculiar epidemic of a mysterious nature, at one time taking the form of pneumonia — so-called infectious pneumonia — at another time encephilitis; at another time and very often, called by the name influenza The reports which have been coming to us quite recently from Germany state that the Germans blame the Chinese imported for work behind the lines for bringing them the disease a year ago, when it crippled the German army. The Austrians say they got it from the Americans, a small force of whom were then in close proximity. Whereas the disease is sometimes called "Spanish grippe," the Spanish people are very much wrought up over the suggestion that it originated there, and say that they first received it from Germany. Whereas the French army say they got their first case from Sweden. The fact that I want to bring home is that this disease is nothing new; that our surgeons and physicians have been commenting upon it for over a year. A whole section of the British Medical Association convention last summer was given up to a discussion of this disease which we now accept under the name of "grippe."

Dr. Brooks has touched upon many facts that we do not know and cannot explain. One very significant recent observation touches this Society intimately, — namely, the so-called shell shock of the trenches. Similar conditions of the brain are found after death from shell shock, and from carbon monoxide poisoning. This suggests some chemical agent as the factor in shell shock. I believe that the members of the medical profession will come to members of the chemical and bacteriological

sciences and ask that this and kindred diseases be studied, not alone from the medical point of view but from the point of view of the bacteriologist and the chemist working jointly.

Coming back to the cases of influenza in this country, it is generally understood that those cases among sailors at South Boston and East Boston in August were the first in the East — practically the first in the United States. The Boston *Herald* of March 18, 1918, however, stated that a mysterious disease had broken out in Chicopee, Mass., during the previous week. Naturally, my first thought was that this might be an occupational disease of some sort. I had it thoroughly investigated and received a report that the Chicopee infection was similar to the old epidemic of 1888–89, and was not occupational in any degree. The Springfield *Union* of March 21, 1918, notes that the numerous cases of a mysterious malady affecting manufacturing plants turned out to be *only* grippe. There is little or no doubt but that those cases were our first focus of the disease in this country. What happened between the appearance of the disease in Springfield in March and the August outbreak of the epidemic we are at a loss to know. We do know of the outbreak among the boys at the South Boston Pier. Dr. Brooks has told us of its appearance on the training ships of the Shipping Board. Its progress and its travel through the country more recently are familiar to all of you.

I want to tell something about the work at the camp hospital so successfully organized by Dr. Brooks. As he told you, we were all baffled by the nature of the disease. Our bacteriologists, Captains Slack and Overlander, were constantly making analyses from the secretions in the nose, mouth and throat, and obtaining not one germ which seemed to be responsible for the disease, but a variety of germs. Sometimes it was the germ of pneumonia which would occasionally appear forty-eight hours before pneumonia developed. In other cases the patient would develop pneumonia and no typical germ would apparently be present. Secretions from the nose failed to give evidence of Pfeiffer influenza germ such as we have associated since 1892 with the epidemic of 1888. That specific bacillus has been practically wanting not only among the cases in Massachusetts

but among those also reported throughout the country. The most typical germ found has been that of pneumonia, and this was not often found in the secretions of the nose and mouth, but by puncturing the lungs, when we would find Types I, II or III.

So that we have, in all probability, in this epidemic, a mixed infection. There is no unanimity of opinion to-day as to what type of bacteria — pneumococci, streptococci, etc. — causes this disease. One peculiarity of the disease is the occurrence of hemorrhages of the nose, the back part of the throat and of the skin. In the lungs we find that the blood vessels are plugged with clot after clot until frequently the area behind the clots was so disabled that it was only a case of a few hours before a large area of the lung was completely occluded from use. The result was that patients quickly became cyanosed. My first thought was carbon monoxide gas poisoning. All the characteristic symptoms of gas poisoning were present, — plugging up of the blood vessels, hemorrhages of the lungs and congestion which prevented the purifying of the blood by oxygen. The blocked areas were frequently in the center of the lung and not readily detected by physical examination.

Medically we have been able to establish certain definite facts which have a public interest, — namely, rather than, as formerly, looking to the temperature curve as a guide to the condition of the patient, we watched the pulse and respiration. We have seen patients die with normal temperature but with pulse and respiration that never came down to normal. On the other hand, patients have become well with temperatures of 105 and 106 but whose pulse and respiration never went very high. We have made this one great contribution to medicine, — namely, that if you wish to guide your patient safely through the crisis, you should watch the pulse and respiration rather than pay attention exclusively to the fever and, secondly, consider each case of influenza a potential case of pneumonia.

Relative to sanitation in the camp we had this problem. It was a civil community, and those knowing Corey Hill can imagine the prejudice we had to meet and the difficulty of trying to establish military discipline. These difficulties were met

and overcome by Colonel Brooks, and the camp successfully established. From the minute the camp was opened no person was allowed to enter the camp without a pass and only under military escort. No one was allowed in the hospital streets without a mask. In the end we succeeded in carrying through nine other camps under similar military discipline, — at Ipswich, Brockton (Fig. 1 and Fig. 2), Fayville, Gloucester, Lawrence, Haverhill, Waltham, Barre and Springfield.

Certain interesting facts developed in establishing such

FIG. 1. BROCKTON CAMP — CONVALESCING PNEUMONIA PATIENTS.

camps in civilian neighborhoods. In the location of such camps, instead of depending on the old-fashioned military latrine, we tapped the sewer and located the latrine in such a way that the sewer became our catchbasin. Ordinary house toilets were fitted over the sewer.

There has been criticism that our patients were out in the cold and wet, exposed to inclement as well as clement weather. That was part of the treatment. But the tents were properly ditched, and the ground under and around them was perfectly dry at all times. Instead of having a floor in the tent we had

a wooden run which came in between the beds so that the nurses, orderlies and doctors could walk in on dry boards from the street, and they could be mopped off frequently and dried. By rolling up the sides of the tents the sun could get in, and the grass remained green under the tents well into September. What other evidence is necessary that conditions were satisfactory? Under the old style of military camp hospital we would have put down floors, the grass would have been destroyed, dampness would have collected under the floors and not been recog-

FIG. 2. INFANTS' WARD — BROCKTON CAMP.

nized until the tents were re-pitched and the site changed. By doing away with the floors we were able to keep the tents in the same location where first pitched. In order to protect the patients from dampness, a paper sheet was put on to the spring of the bed and also over the patient, and instead of loading them with three or four blankets we simply gave them one blanket, a paper blanket and a very light covering over that. Even on the coldest nights they said they were perfectly comfortable. In crises, hot bricks or metallic bottles were used to give addi-

tional heat. All the nurses and orderlies on duty during cold nights were supplied with what were termed pneumonia jackets, made of padded paper and worn under the sweater. On very wet and disagreeable days early in September, rubber boots and coats were furnished by the Shipping Board for nurses, doctors and orderlies, so that it can be seen that no unnecessary exposure to inclement weather was demanded, and nothing was left undone for the comfort of the nurses and orderlies serving us.

Another innovation was the incinerator. Ordinarily in military hospitals this is constructed with a good deal of detail, expense and labor, and so that it will look well. Our problem had to be solved very quickly as a patient died practically before we could make a diagnosis, and it was thought necessary to burn everything which had come in contact with him. Bricks were placed around the hole of the incinerator and the head of an iron bed was laid on these bricks to form a grate, and we continued to use this device during our stay in that camp. This improvised incinerator proved very satisfactory. To erect a supplementary kitchen we took the side rails of the beds, parallel to each other, and laid two short ones across. This served admirably for boiling the water which we kept on hand all the time for disinfecting materials and dishes.

We separated influenza cases from pneumonia cases. One of the observations made at our camp, as stated before, was that every case of influenza is a potential case of pneumonia, and the sooner this is recognized the sooner the death rate from pneumonia will begin to diminish. It was from acting on that belief that our camps attained the low mortality which we can claim for our treatment. Whereas we got only 351 cases of influenza we had something like 120 pneumonias. We were always looking for pneumonia, and by taking those precautions that we would use for pneumonia cases, such as looking after the pulse and respiration carefully, we were able to anticipate cases of true pneumonia. Two very competent bacteriologists, Dr. Slack and Dr. Overlander, were with us constantly, making all sorts of investigations, which we have included in our reports to the state.

The experience at Corey Hill served as a training school for

doctors and nurses and orderlies, which has been used throughout the state and in other states of this union. Dr. Brooks could have told you of calls from other states, asking that we send so-called "Brooks Units," in order to combat this disease then making its appearance in other localities. By the training we gave nurses and orderlies at Corey Hill many lives have been saved, and, as the Public Safety Committee has said, the work done in these various camps has saved the state 10,000 lives. We were at the camp something like six weeks, and then went to other cities and towns and established there similar camps. The Corey Hill per cent. of deaths was 10.25 of those treated, and the per cent. of deaths of those seriously ill among the boys on the training ships was but 3. At the Cooke Hospital in Chicago, one of the finest in the country, during this epidemic there was a mortality of 31 per cent., yet the editorial read by your chairman would seem to indicate that they think they got out of it very lightly indeed, while we have a death rate of 3 and 4 per cent., at some camps, our highest running to but 16 per cent. You must also realize that 39 per cent. of the cases in this high death rate died within the first twenty-four hours.

Most of the cases received at our hospital were boys between eighteen and twenty-four years, supposed to have been physically fit. They had been struck down like little children. This disease has no respect for the strong, nor for sex. The belief that one attack guarantees immunity from another is not sustained by any investigation that has seemed worth while. Some contend that the fact that so many young people contracted it this time whereas elderly people who might have had it in 1888–89 escaped, is significant. This opinion is not confirmed, however, by trustworthy investigation. The disease spreads by personal contact. All pandemics have followed travel, and only so fast as travel goes; in the East with the speed of the caravan; in European countries in accord with their interchange between countries; in this country more rapidly because we are less severe in our restrictions on travel. All authorities seem to agree on this fact, — it passes from person to person, either by direct contagion, by droplets, sputum, sneezing, etc.

Now, briefly as to prophylactics. Dr. Brooks described the

masks. Gauze is the best thing known for straining the air from influenza germs. By observation we have found that the corners of the mouth form a perfect incubator for germs, and if the mask is removed and then put on wrong side out the result is often disastrous. Dr. Brooks therefore advised, on the second day of our camp, that we use an old-fashioned tea-strainer with the handle removed and bent to fit over the nose and cover the mouth. This was covered with several layers of gauze. First we tried treating the gauze with medicated powder, but this made the wearer sneeze and cough, just what we were trying to avoid. We did not require the patients to wear masks because they were already struggling for air, and we did not want to cut off any air with two or three layers of gauze. It is important that the mask should fit properly and be so arranged that it covers the mouth but has no opportunity to touch the lips or nostrils. Every two hours the doctors, nurses and orderlies are required to go to headquarters and drop the mask into boiling water and then receive a new mask which is handed out through another opening in the same building so that the recipient does not need to go into the building. The gauze removed and disinfected is used in sputum bags attached to the beds of the boys. One of the most helpful devices we have discovered is the pinning of an ordinary manila bag to the patient's pillow and then giving the boys some of the used gauze for expectoration, after which they drop the gauze into the bags and the whole thing is later burned up. Another precaution which was insisted upon was the washing of the hands. In the streets between the tents were tables with basins containing a 1 1000 solution of corrosive sublimate solution, and before nurses or orderlies could go to mess they had to report at headquarters and under supervision wash their hands in this solution. One hears a great deal about vaccine which might prevent influenza, and of experiments which have been performed. One experiment in our state was most conclusive. Secretions were taken from the noses of two well-authenticated cases of influenza at the Chelsea Naval Hospital and three hours later taken down to the Island where nine men had volunteered for the experiment. The secretion was injected into the noses of these men but not one of them con-

tracted influenza. Secretary Daniels recommended that these men be recorded as heroes to the cause of preventive medicine. There is a great deal of local enthusiasm at present with regard to the use of vaccines. The laity seems to have concluded that if they get a dose of the anti-influenza vaccine they are free from danger of contagion and need not take precautions. The United States Government is now talking of combating that false sense of security, and in a report recently received the U. S. Public Health Department states that the use of vaccine for preventive purposes does not yet seem to be justified by the results. It is yet experimental.

The data obtained on the use of pneumonia antitoxin is somewhat more conclusive. The experiments made on Navy men with anti-pneumonic solution seem to have given splendid results. Out of 12 000 men who have received the solution, practically none have developed the disease. It has, however, this limitation, — that it claims to affect Types I, II and III only; and, secondly, it is the conclusion of those who have used the antitoxin that it must not be given to those having any fever or acute colds. In other words, it cannot be given to any having influenza, in order to prevent pneumonia, as it would in all probability only aggravate the case and precipitate pneumonia. Neither can it be used as a cure after pneumonia has developed. It promises to be an effective preventive of pneumonia.

This history of the disease might be continued almost *ad libitum*, but one thing I do want to emphasize, namely, the great impression it made on those whom we were treating. Many of the boys had never been away from home before; they were in a strange port, having enlisted in a spirit of loyalty. They became ill and were taken away in the night, they knew not where; and what impression did they receive? A quarantine was declared even on letterwriting, in order that the boys might not put pencils in their mouths and thus run the chance of transmitting the disease. Dr. Brooks commanded all letters written by the boys should come to the medical officers for censorship. I was anxious to see how the boys' minds were working, and give the following excerpt from one of the letters:

"*My dear Mama*, — I wonder what you are doing for yourself to-day. I hope that you are all well. Mama, I thought I would write you this morning as I am feeling better. I am in the hospital. I thought at first that I would not write about me being sick, but changed my mind this morning, but Mama don't be uneasy about me for the doctors and nurses are so good. I was brought here yesterday eve. You know when any one gets a bit puny they will send them to the hospital. . . . Mama, there is no place like home when any one is sick, and there is no hand like a dear old Mother's. No one knows how to appreciate a Mother until they get away, but if there was ever a place that could take a place of home this is the place. I hope to be able to go back to my ship in a few days. . . . Mama, don't be uneasy about me for I am well taken care of. What are the little pets doing? Don't tell them about uncle being sick. I wish I could see them. Say, how much cotton haul have you got out. . . . Kiss the little darlings for me and with a big true heart full of love, I am, Your boy. (Discharged well.)"

One difficulty we experienced in other camps established was the obtaining of the necessary doctors and orderlies. These boys now granted a furlough heard the story and all volunteered their services. In every one of the camps our great mainstay has been these boys who gave their services in gratitude for what our state had done for them in their sickness.

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THE INFLUENZA EPIDEMIC AT THE RECEIVING SHIP, COMMONWEALTH PIER AND THE NAVAL CAMP AT FRAMINGHAM.

By Lieut. R. W. Mathes, Assistant Medical Officer, U.S.N.R.F.

(Presented before the Sanitary Section, November 15, 1918.)

It may be of some interest to know a little about the conditions at Commonwealth Pier during the influenza epidemic, as the Receiving Ship was given the credit for being the instigator of the plot. It is generally understood that the first cases came from the Pier, although the disease broke out at the Receiving Ship and at East Boston at practically the same time. It is not to be wondered that the Pier should have had the first cases, as the pandemic traveled from east to west, and we are the Receiving Ship of Boston. Transfers are made to and from us, and no doubt the first cases which came to our attention were in men coming back from across the water. I have been given to understand by some of the officers on duty in France that the epidemic was raging in Brest during June and July, in fact, one officer told me himself that he spent three weeks in the hospital.

The first cases we saw were on August 27, when two men reported as sick. The disease was thought to be influenza of the usual type and character.

I will quote a few figures to show the rapidity with which this epidemic traveled:

August 27, 2 cases; August 28, 8 cases; August 29, 28 cases; August 30, 71 cases; and for succeeding days 61, 92, 104, 80, 11, 23, 13, and so on for quite a period, namely four or five days, when we received a large draft of several hundred men, and then another rise in number started as 15, 43, 39, 27, 17 and 11.

Washington, of course, immediately took cognizance of the fact that we were having an unusually large number of cases, and steps were immediately instituted, in so far as was possible, for relief.

The Receiving Ship has an average daily personnel of from 4 500 to 5 000 men, but transfers and drafts complicate the count, so that between 8 000 and 10 000 men frequently pass through the Receiving Ship each month.

Commonwealth Pier having received a more or less black eye, was of course under constant sanitary inspection, but there has never been a sanitary or medical officer who has inspected the ship but what he has expressed himself as more than pleased with the sanitary arrangements.

The medical authorities had said that they wanted somewhat to relieve congestion, although, according to the inspectors, the amount of air space, etc., was ample. Consequently, on September 12 a camp was started at the old militia grounds at Framingham, Mass., with a working party of twenty-four men. On September 13, 125 men were on hand to get things in shape, and arrangements were made to procure tents and the necessary other equipment from the various naval supply depots.

It was the purpose to keep the camp open as long as the weather permitted, and it was deemed advisable to do away with the old ditch latrines and to construct latrines which would have a direct connection with the sewer. It was thought the camp could exist until about this date, the 15th of November.

On the following day 1 000 men were sent out, and these were followed by daily drafts of one hundred or more as rapidly as possible. The maximum complement has been 2 800 men as against 1 800 men at the Pier. The average complement for

the week ending September 21 to the week ending November 9 was 2 045, and the average complement during the same period at the Receiving Ship was 2 325. During this period there were 277 cases of influenza at the Receiving Ship, as against 52 at Framingham. Drafts have been received at both stations of men who have been exposed to the infection in various places before their arrival in the First Naval District.

For statistical purposes it may be said that practically the same number of men were quartered at each station, the above figures showing that 11.05 per cent. contracted influenza at the Pier, and only 2.05 at the open-air camp at Framingham.

I believe that this very clearly shows the value of the open-air treatment as a prophylaxis, for, as nearly as we could determine, the men at these two stations before arrival in the district were exposed in equal manner to the infection.

The medical officer was instructed to keep only the mild cases at the Pier, as the facilities were limited to care for such a large number of sick men, not as regards hospital equipment, but as to hospital space. The more serious cases were transferred at once to the Naval Hospital, Chelsea, and to various other hospitals and stations designated by the naval authorities.

I shall not endeavor to speak on the treatment of this disease because only the mild cases were kept under our direct observation. I think the facts as above stated show that the value of open-air treatment cannot be too strongly emphasized when we consider the percentage cf those contracting the disease living indoors as compared with those living outdoors.

DISCUSSION.

Dr. Harrington. — All of the tent hospitals were modeled on the so-called Brooks No. 1 on Corey Hill. The shack designed by Dr. Brooks and equipped for the treatment of influenza and pneumonia cases — in fact for any case requiring fresh air and sunlight — is so arranged that the side shutters can be let down when storms come from the south or southwest. The rear space provides an eave which permits of the circulation continually of a current of fresh air underneath it. We can now have a series of rooms with but two patients to a room.

Pneumonia patients out in the street become sunburned while receiving treatment. Contrast this with the old-time treatment of piling on blankets, giving hot drinks, shutting out all the air. Now we put them out in the sun and air and get more cures than by any other treatment.

At Springfield the coughing became so distressing that everybody lost their nerve. Dr. Brooks went up there and took 92 cases out of the hospital, putting them in tents. The next day the visiting physicians asked, "What have you done for these boys? They have stopped coughing. I have been here an hour and they haven't coughed at all. It does not seem possible they are the same men." That is how men who were skeptical and inclined to oppose the treatment became converted, — by the results. I have no hesitation in saying that the treatment of pneumonia in the future will be towards the methods established during this epidemic.

ALMON L. FALES.* — Do you consider the war responsible for the epidemic — or, putting it another way, should we have had this epidemic if it had not been for the war?

DR. HARRINGTON. — I do not dare answer; although I have it on pretty good authority that the morale began to break when the soldiers in the German army began to hear that their wives and kinspeople were all being taken down with the disease.

But I do want to say a word of warning. In a medical journal received to-day there is an account from Madrid that the disease has broken out there again, and that warns the rest of the world to be cautious. Madrid is more upset now than it was when 2 000 000 were reported sick with the disease last spring, and the reports from the camps in Europe also show a revival of the disease among the troops on the western front. I am wondering whether we shall not get it again in this country with the coming home of these boys. This is a serious problem, but we have the consolation that Massachusetts is pretty well organized to combat it, under the State Guard and with Dr. Brooks ready to meet the disease once more. I think we are better qualified in this state than is any other state of the Union.

MR. ALBERT MORSE. — Among the other volunteers at

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Corey Hill I helped for two weeks. I wonder if you could tell me the reason for one thing I noticed, — that most of the people sick with the disease were heavy people, weighing 200 to 250 pounds. Has the blood pressure something to do with it? Those that died were big, husky men rather than the thin people.

Dr. Harrington. — It is a clinical observation that when an athlete does get pneumonia he usually dies, whereas the weakling seems to have more or less antitoxin within him. Blood pressure is not a factor. From observations of 2 000 cases in the Chicago Hospital it has been concluded that blood pressure indicates some kidney disorder.

I want to add that women in a delicate condition should not be allowed to come in contact with people suffering from influenza. Women in a family condition invariably die, the death rate being 100 per cent. These women invariably develop quickly cyanosis. They seem to be more susceptible. From a large grouping of cases in Chicago it has been ascertained that pregnant women have a mortality rate of 47 per cent. There have been some tragedies right here in Boston, where women have paid the penalty with the unborn child.

Alfred O. Doane.* — Does spraying have any value?

Dr. Harrington. — An infected ear is one of the most common evidences of infection. We apply argyrol ointment (10 per cent.) to the nasal mucous membrane as a preventive, and also use Dobell's solution as a gargle and mouth wash. This is used in nearly every hospital. It is an alkaline solution, and it is well known that germs cannot live so long in an alkaline solution. Nature gives us in the mouth and nose an alkaline solution. It is only when this becomes acid, through fatigue or some disorder, that germs grow in the mouth. Then trouble follows. Spraying and gargling with alkaline solution is of some value. It will not prevent germs but will discourage their growth when they are once in the mouth.

Dr. Brooks. — At Thompson's Island there is a total at the Farm School of about eighty boys. During the height of the epidemic Dr. Bradley, who is in charge, kept the school under

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quarantine. No one was allowed to go near them or mingle with them. Last week, when everything was believed to be all right, some boys were allowed to come up to town.

Yesterday morning Mr. Bradley called me up and gave me these facts. The day before he had had one boy sick, and thought it might be influenza but was not quite certain. Yesterday morning he had 4 cases, last night he had 11, to-night he has 17. The quarantine was allowed to lapse too soon, and they are paying the penalty. The warning of Dr. Harrington is very apt. When the disease begins to decline every one gets careless, and I am afraid we shall have to pay the penalty.